

**DOCKET NO: A-93-02
V-B-12**

**TECHNICAL SUPPORT DOCUMENT FOR
SECTION 194.23: PARAMETER REPORT**

VOLUME 1 OF 3

**U. S. ENVIRONMENTAL PROTECTION AGENCY
Office of Radiation and Indoor Air
Center for the Waste Isolation Pilot Plant
401 M. Street, S. W.
Washington, DC 20460**

APRIL, 1998

Technical Support for this document was provided by TechLaw, Inc. and its subcontractors under EPA Contract 68D50174.

TABLE OF CONTENTS

VOLUME I

EXECUTIVE SUMMARY	1
1.0 INTRODUCTION	2
1.1 Background and Scope	2
1.2 Report Structure	3
2.0 CCA PA PARAMETER DOCUMENTATION AND REVIEW STRATEGY	4
3.0 STAGE I REVIEW: DATABASE COMPILATION	6
4.0 STAGE II REVIEW: DATABASE SCREENING AND EPA TECHNICAL REVIEW ..	7
4.1 Database Screening	7
4.2 Technical Review	8
5.0 STAGE III REVIEW: TECHNICAL REVIEW SCREENING	9
5.1 Preparation of Summary Tables	9
5.2 Identification of Inadequately Supported Parameters	9
5.3 Identification of Issues	11
6.0 STAGE IV REVIEW: DATA RECORDS PACKAGE REVIEW	15
7.0 RESULTS AND CONCLUSIONS	17
7.1 Parameters Lacking Supporting Evidence	17
7.2 Parameters that have Records Supporting Values other than those Selected by DOE	17
7.3 Parameters Not Explicitly Supported by the Relevant Data/Information	17
7.4 Remaining Issues	18

Figures

- Figure 1. Parameter Documentation Process.
- Figure 2. Example Data Base Parameter Data Sheet.
- Figure 3. Example Technical Review Data Sheet
- Figure 4. Example Summary Sheet for Technical Review Parameters.
- Figure 5. Example Data Records Package Review Template

Tables

- Table 1. Inadequately Supported Parameters Identified in EPA's March 19, 1997 Letter

VOLUME II

Appendices

- Appendix A. List of Data Base Parameters
- Appendix B. Technical Review Sheets
- Appendix C. Technical Review Summary Sheets
- Appendix D. Data Package Technical Review Sheets
- Appendix E. Support Sheets for Poorly Justified Parameter Designations

VOLUME III

ATTACHMENT SR: SUPPLEMENTAL PARAMETER REPORT

Exhibits

- Exhibit SR-1. Examples of the form the roadmaps will take in the parameter documentation guidebook.
- Exhibit SR-2. Designation of legacy and placeholder parameters.
- Exhibit SR-3. Memorandum providing technical basis for parameters previously classified as being based solely a professional judgement.

Appendices

- Appendix SR-A Intermediate Tables from "EPA Database"
- Attachment SR-1 Footnotes for Attachment SR-2
- Attachment SR-2 Main EPA Database
- Attachment SR-3 Parameters based on Empirical Data
- Attachment SR-4 Codes
- Attachment SR-5 References for Attachment SR-2
- Attachment SR-6 Additional Sources
- Attachment SR-7 Enhanced Sources
- Appendix SR-B CCA Parameter Traceability Guide
- Appendix SR-C(a) Backup information for Parameter 181 DRZ_0 - PRMX_LOG
- Appendix SR-C(b) Backup information for Parameter 2231 WAS_AREA - SAT_WICK
- Appendix SR-D(a) Cover Page and Outline of Analysis Package for Salado Flow Calculations
- Appendix SR-D(b) Supporting References for Professional Judgement Parameters

LIST OF ACRONYMS

AP	Analysis Package
CCA	Compliance Certification Application
DOE	U.S. Department of Energy
DQC	Data Quality Characteristic
DRP	Data Record Package
EPA	U.S. Environmental Protection Agency
JR	Justification Report
PA	Performance Assessment
PI	Principal Investigator
PIRP	Principal Investigator Record Package
PR	Parameter Report
PRP	Parameter Record Package
PRT	Parameter Review Team
QED	Qualification of Existing Data
SA	Sensitivity Analysis
SNL	Sandia National Laboratories
SWCF	Sandia WIPP Central File
WIPP	Waste Isolation Pilot Plant
WPO	WIPP Project Office

EXECUTIVE SUMMARY

This report describes the Agency's review of the parameters documented in the U.S. Department of Energy's (DOE) WIPP Compliance Certification Application (CCA) of October 1996. The parameter values were inputs to the series of performance assessment computer models used in the CCA to demonstrate compliance with EPA disposal standards. The Agency performed a comprehensive review of the parameters and the parameter development process. Approximately 1600 parameters used in the CCA Performance Assessment calculations were given a general review by the Agency, and detailed technical reviews of Parameter Record Packages and supporting documentation were performed by the Agency for more than 400 parameters important to performance of the disposal system. Records reviewed include the CCA, Volume 1, Chapter 6, Tables 6-8 through 6-27, pp. 101 to pp. 166, Volume XI, all of Appendix PAR, WIPP parameter entry forms (464 Forms), Parameter Records Packages (PRP), Principal Investigator Records Packages (PIRP), Analysis Packages (AP), and Data Records Packages (DRP).

The Agency first examined the sources of the parametric values used in the computer codes. The Agency found that 416 (26.4%) of the 1571 parameters used in the CCA PA calculations were well-established constants found in general literature and general engineering knowledge. The Agency found that DOE derived 887 (56.6%) of the parameters from experimental data, either from its own experiments or from journal articles. The Agency also found that 89 (5.7%) were waste-related parameters derived from the DOE's waste inventory database, that DOE selected the values of 149 (5.9%) parameters using the professional judgement of its employees, and that approximately 194 (12.3%) parameters were "legacy parameters" originally used in DOE's 1992 PA and incorporated in the CCA PA without change.

Parameter documentation was reviewed by the Agency in a staged process, progressively screening parameters to identify those that were most important to the final CCA PA calculations and had not been adequately supported. In the final screening, the Agency identified 58 parameters that remained inadequately supported and required further evaluation. DOE was informed of those parameters in an Agency letter in March 1997. The final disposition of those parameters is described in the Agency's Technical Support Document for Section 194.23: Parameter Justification Report (Docket: A-93-02, V-B-14). At the conclusion of its review, the Agency also informed DOE of six issues that remained unresolved regarding parameter documentation. Resolution of those issues is described in Attachment SR to this report.

1.0 INTRODUCTION

A comprehensive review was conducted by EPA of the supporting rationale for the parameters used by the U.S. Department of Energy (DOE) in the Waste Isolation Pilot Project (WIPP) Compliance Certification Application (CCA) of October 1996. These parameters were inputs to a series of performance assessment (PA) computer codes used by DOE to determine compliance with EPA disposal standards. This report describes the DOE's PA database and its documentation, the process used by the Agency to conduct its review of DOE's supporting documentation and technical rationale, and the results obtained.

1.1 Background and Scope

This report is one in a series of three reports that provide documentation of EPA's technical review of the CCA and the methodology used by the Agency to evaluate DOE compliance with the requirements of 40 CFR 194.23(c)(iv). These three reports are briefly described in the following paragraphs.

This report, *Technical Support Document for Section 194.23: Parameter Report (PR)*, describes EPA's comprehensive review of the parameters used in the PA model. The report describes the screening process used by the Agency to identify those parameters that were poorly documented, that have a weak technical basis, and that may be important in determining compliance. This screening occurred in several steps and culminated in identifying a series of parameters that warranted further review. Those parameters were listed in Enclosures 2, 3, and 4 of the Agency's March 19, 1997 letter to DOE (Docket A-93-02, II-I-17).

The report, *Technical Support Document for Section 194.23: Sensitivity Analysis Report (SA)* (Docket No. A-93-02, V-B-13), describes the Agency's evaluation of key PA model outputs to changes in selected input parameters. The input parameters selected for this analysis were based primarily on the results of the parameter review and most of those parameters were identified to DOE in the aforementioned Agency letter of 19 March 1997 (Docket A-93-02, II-I-17). However, additional parameters or groups of parameters were added to the analysis based on the initial results of the Agency's sensitivity studies and on concerns for specific parameters and processes expressed during EPA's public hearings and in public written comments. (see EPA letters of April 17, 1997 (Docket A-93-02, II-I-25) and April 25, 1997 (Docket A-93-02, II-I-27).

This report, *Technical Support Document for Section 194.23: Parameter Justification Report* (Docket No. A-93-02, V-B-14), is referred to as the Justification Report (JR). It describes the disposition of the inadequately supported parameters described in the Agency's letter of March 19, 1997 (Docket A-93-02, II-I-17). This disposition was based on the results of the Agency's sensitivity analysis, additional supporting information provided by the DOE, and further analysis by the Agency. Parameters were removed from the list by the Agency if, for example, PA performance measures were found to be insensitive to them, if the additional DOE supporting information was found to be adequate, or if upon further review the Agency determined that DOE's supporting rationale was acceptable. The disposition of these parameters was described to DOE in the Agency's letters of April 17, 1997 (Docket A-93-02, II-I-25) and April 25, 1997 (Docket A-93-02, II-I-27). Parameters that were not removed from the list were used in developing a revised data base of parameters of major concern to the Agency for use in the EPA-

mandated Performance Assessment Verification Test (PAVT). The PAVT is designed to provide a comprehensive test of the effects of changes in significant, uncertain parameters and changes in other aspects of the CCA PA computer codes on the PA compliance calculations presented by DOE in the CCA.

The parameter review described in this report was conducted to verify that the parameter values used in PA were developed and documented in accordance with the standards required by the Agency in 40 CFR 194.23(c)(4). This review was performed in four stages. Beginning with the approximately 1,500 parameters identified in the PA database, originally listed in file CCA8.SDB in the DOE/SNL CMS, the review culminated in identifying 58 parameters that were inadequately supported and required further detailed evaluation. DOE was notified of these parameters in the Agency's letter of March 19, 1997 (Docket A-93-02, II-I-17).

This parameter review was performed by a Parameter Review Team (PRT) comprised of Agency staff and contractors. The review was supported by Sandia National Laboratory (SNL) staff. The review was conducted from November 1996 to March 1997.

1.2 Report Structure

This report is divided into seven sections. Following the introduction, Section 2 describes DOE's CCA PA documentation approach and development of the Agency's review strategy. Section 3 describes the CCA PA database compilation by SNL. Section 4 describes the Agency's database screening and technical reviews of the screened parameters. Section 5 describes the Agency's screening of the technical review information that resulted in the list of 58 parameters that were identified to DOE as being inadequately supported. Section 6 describes the Agency's review of Data Records Packages for selected parameters that were based on either field or laboratory measurements. Results and conclusions are presented in Section 7. The subsequent resolution of key issues identified during the Agency's parameter review is described in a Supplemental Report presented in Attachment SR. The main text and Supplemental Report are supported by Appendices, Figures, Tables, and Exhibits that are listed in the Table of Contents.

2.0 CCA PA PARAMETER DOCUMENTATION AND REVIEW STRATEGY

Documentation supporting development of the CCA PA parameter database is maintained in the Nuclear Waste Management Records Center at Sandia National Laboratories (SNL) in Albuquerque, New Mexico. Under SNL's records management system, this documentation is compiled by parameter in Parameter Records Packages (PRP). Each records package contains an SNL Form 464 that summarizes the final parameter values used in the CCA PA and provides references to the data sources and rationale used to develop those values. The supporting information includes Principal Investigator Record Packages (PIRP) which describe how the data points and other information were interpreted to determine the parameter values, Data Record Packages (DRP) which contain the actual data points collected, internal memoranda which provide interpretative explanations and issue resolution, and independent technical reports. Additional information is found in the CCA, particularly in Chapter 6 and Appendices PAR, MASS, and PEER (Docket A-93-02, II-G-I, Volumes I, XI, XII through XV). Analysis Packages (AP) include parameter information used to supplement the information in the CCA and describes the approach taken to develop the parameter values (Docket A-93-02, II-G-04 through II-G-11). A flow chart illustrating DOE's parameter documentation process is presented in Figure 1.

The documents are retained within the Records Center in the Sandia WIPP Central File (SWCF). The documents are assigned WIPP Project Office (WPO) numbers and are coded to indicate those originating in Albuquerque (A) and Carlsbad (C). The WPO number is the most convenient way to identify and retrieve stored documents and is extensively used by the Agency for reference purposes. As discussed in this report, the parameter review team (PRT) found gaps in this documentation, as not all parameters were supported by complete, traceable records.

The Agency's parameter review was divided into four stages, each with a specific primary focus and point of completion.

Stage I. Compile the CCA PA database for Agency review and develop initial review methodology.

Stage II. Implement initial review methodology developed in Stage I and screen all CCA PA database parameters for traceability of the parameter values from the data sources, their use in the PA, the type of information used to develop parameter values, the suitability of DOE's parameter value development process, and the methods used by DOE to qualify existing data. This screening is primarily based on the Parameter Record Packages for the database parameters. Identify those parameters requiring technical review by the parameter review team and develop and implement the technical review methodology.

Stage III. Evaluate the traceability and technical validity of the parameters identified in Stage II as requiring technical review and compile a final list of potentially significant and inadequately supported parameters for transmittal to DOE. This stage focused on review of the Principal Investigator Record Packages for those parameters.

Stage IV. Further evaluate the traceability of parameter values and the use of Data Quality Characteristics (DQCs) in DOE's data collection process by reviewing the Data Record Packages. Identify outstanding issues for further Agency review.

3.0 STAGE I REVIEW: DATABASE COMPILATION

In Stage I of this review, SNL was requested to prepare a complete database of all parameters used in the 1996 CCA PA. The Agency used one of the Secondary Data Base (SDB) files found in the SNL CMS system (file: CCA8.SDB) as the starting point. As a result of this effort, 1,571 parameters were identified and are listed in Appendix A.

The objectives of this stage were to familiarize the parameter review team with the SNL parameter record management system, classify the parameter types used in the CCA PA calculations, review selected parameters for adequate documentation and technical viability, identify the information needed by the Agency to perform its initial review, and work with SNL to develop a CCA PA parameter database that supplies that information.

The Agency determined that its initial review would be based on the following six categories of information: (1) whether the parameter is in the database; (2) the parameter category based on source of information; (3) the type of data used by DOE in developing the parameter values and their distributions; (4) the appropriate use and documentation of professional judgement in developing the parameter values; (5) the methods used to qualify existing data; and (6) the completeness of documentation and traceability from the parameter value to the data source. Figure 2 shows an example of the table developed to record this information. This is the same table as used in Appendix A to list the database parameters. The column headings and footnotes to that table provide instructions for the review process and additional details for each of the six review categories. SNL provided the information for all columns except for the categories of professional judgement and traceability. These categories are regulatory criteria and were completed by the Agency. The Agency requires parameters based only on “professional” judgement without supporting data to have a formal expert elicitation process for determining appropriate values. The Agency considers traceability to a technically adequate basis to be an essential element of parameter documentation.

The six review categories provided the information needed by the Agency to make a preliminary identification of those parameters that were potentially important to the PA calculations and that may be inadequately supported. The parameter review team attempted to limit its focus to those parameters deemed important to the PA results; however, the existing DOE CCA Sensitivity Analysis (Docket A-93-02, II-G-I, Volume XVI, Appendix SA) was not specific enough to provide a basis for excluding parameters based on this criterion. A determination of inadequate parameter support could result from questions of data quality, technical viability, or adequacy of documentation. The information needed to complete the Appendix A tables could generally be obtained from the Parameter Record Package, facilitating efficient review of the large database. When completed, a person familiar with the classification codes could readily identify apparent weaknesses in the parameter’s supporting information. These tables were used as the basis for the Agency’s database screening conducted under Stage II. Stage I was completed when the parameter database listed in Appendix A was developed. Other parameters were subsequently added to this list during resolution of the issues identified during Stage IV, and the final parameter database is presented in the supplement to this report (Attachment SR-2).

4.0 STAGE II REVIEW: DATABASE SCREENING AND EPA TECHNICAL REVIEW

4.1 Database Screening

In Stage II, the information assembled in Stage I for all CCA PA database parameters listed in Appendix A was screened to identify parameters that were not adequately supported under the six review categories described in Section 3 of this report and required technical review by the Agency. This screening resulted in identifying 465 parameters for additional, more detailed evaluation. The balance of the parameters were considered technically adequate and appropriately documented for use in the CCA PA.

When implementing Stage II, the parameter review team first examined the sources of the different parameter values used in the PA. In overview, 416 of the 1571 parameters were well-established constants found in general literature and general engineering knowledge. The parameter review team also found that DOE derived 887 parameters from experimental data, either from its own experiments or from journal articles. Additionally, 89 parameters were waste-related and derived from the waste inventory report (see Docket A-93-02, II-I-1, Volume III, Appendix BIR), 149 parameters were identified by DOE as having been selected using the professional judgement of SNL personnel, and 194 parameters were “legacy parameters” originally used in DOE’s 1992 PA and incorporated without change in the 1996 CCA PA (see Docket A-93-02, II-I-31, Comment No. 11; legacy parameters are documented by SNL in WPO # 44202). These parameter source categories are not exclusive (for example, a parameter may be a legacy parameter and also be derived from experimental data), and the total number of parameters by type exceeds the total number of different parameters in the database.

Another category of parameter identified by the parameter review team is the “placeholder parameter.” A placeholder parameter is a parameter which, strictly speaking, should be inactive or not used in the WIPP parameter database but has been allowed to remain in the database as an inert place holder to facilitate the correct reading of other parameters. These parameters do not affect the modeling results and are therefore not important to compliance.

Information that supports an evaluation of the quality of the data is called a Data Quality Characteristic (DQC). Documentation of DQCs is required by the Agency for data used to support the parameter values used in the CCA (see 40 CFR 194.22(c)). DQC information was clearly documented or inferred indirectly for CCA parameter values supported by laboratory and field data. However, the level of detail and extent of application of DQCs were not consistently addressed. Sometimes the experimental program plan would require the use of a written data acquisition procedure addressing, for example, the expected measurement accuracy, calibration requirements, or instrument tolerance. The laboratory documents, such as PI lab notebooks, often showed a definite concern about the measurement quality and accuracy, and sometimes measurements were taken more than once because of concerns about confidence in the results. While some of the data were subjected to a Qualification of Existing Data (QED) and/or a peer review process to establish their validity, at the time of the parameter team’s review the records did not adequately document the results of those activities. More recent data collection activities show definite documentation and application of DQC objectives in developing and implementing measurement plans. DQC information was documented by the Agency for key CCA parameters supported by laboratory and field data during Stage IV and is further discussed in Section 6 of this report.

The Appendix A lists provided sufficiently detailed information on the CCA PA parameters to allow the Agency to make an initial evaluation of their importance to the CCA PA results and their compliance with the requirements of 40 CFR Sections 194.22 and 194.23(c)(iv). Based on the information in Appendix A, the Agency selected 465 parameters for technical review. Those parameters are shaded in the Appendix A tables. This selection was based on the following criteria:

- ◆ Parameters were selected that appeared to be important to compliance and seemed to be poorly justified, such as material permeabilities and porosities, particle sizes, Castile brine pocket characteristics, gas and brine pressures, actinide solubilities, and waste inventory information;
- ◆ Parameters were selected that seemed to be poorly justified and controlled various functions of the CCA PA computer codes that appeared to be important to compliance, such as the threshold for anhydrite permeability increases and the dispersivity characteristics of the Culebra; and
- ◆ Parameters were selected for the Agency's use in evaluating the overall quality of DOE's documentation traceability, such as reference constants and general reference values.

4.2 Technical Review

A detailed technical review was performed for the 465 parameters selected in the Stage II screening. An example of the data sheet used in the technical review is presented in Figure 3. The collected information emphasizes the distribution type, basis for determining the parameter value, references to the information sources, quality assurance information, an assessment of the parameter's potential impact on radionuclide transport predictions, and reviewer comments. Stage II was completed when the technical review sheets presented in Appendix B of this report were completed for the 465 parameters.

5.0 STAGE III REVIEW: TECHNICAL REVIEW SCREENING

Stage III consisted of screening the 465 parameters that were given reviews in Stage II to develop a final list of parameters that were potentially important to PA results and were inadequately supported.

5.1 Preparation of Summary Tables

To facilitate the Stage III screening review, information documented on the technical review sheets in Appendix B was compiled in summary form on the tables in Appendix C. The parameters are presented in groups to facilitate identification of analogous parameter values (all parameters in an analogous group were assigned the same values) and in alphabetical order (where analogs are present). The tabulated information includes an evaluation of parameter traceability and the apparent use of professional judgement in determining the parameter value (using the same evaluation criteria that were applied during the initial screening), the degree of technical justification, recommendations on whether the parameter should be sampled or further developed on a discrete basis, and information on whether the parameter was based on laboratory or field data. An example summary parameter review table is presented in Figure 4. Guidance for completing the technical review is provided in footnotes on the sheet. These summary tables were used by the Agency in identifying those parameter values that were important to performance assessment and were inadequately supported in DOE's documentation.

5.2 Identification of Inadequately Supported Parameters

For parameters that were developed based on a literature search, the Parameter Record Package typically provided an adequate documentation of parameter development. However, the Agency's technical review included an evaluation of the traceability and technical validity of the parameter values by reviewing the Principal Investigator Record Packages as well as the previously gathered information in the Parameter Record Packages for all of the 465 parameters, including those based on literature searches and those based on field and/or laboratory data. The 465 parameters were reviewed using the same three criteria that were applied in Stage II to screen from 1,571 parameters down to 465 parameters, but benefitting from the additional information collected during the technical reviews.

The principal focus in this screening was on parameters that were not well justified and that were potentially important to performance assessment. Those parameters that remained poorly justified following the more detailed technical review were identified on the basis of poor traceability, questionable technical support, and an overall rating of being poorly justified on the Appendix C summary tables. Suspected legacy parameters were generally poorly supported and were carefully reviewed. Consideration in parameter screening was also given to a parameter review team recommendation on the tables that the parameter should have been treated differently in the CCA by capturing its uncertainty through sampling or by developing different parameter values. The degree of importance of a parameter to performance assessment was necessarily a judgement of the parameter review team, as the Agency's SA had not yet been completed; however, this was an important element of the final screening that benefitted from the technical review that the Agency had completed.

Based on the Agency's Stage III screening, 58 parameters were determined to remain potentially important and inadequately supported in DOE's documentation not including analog parameters. These parameters are listed in Table 1 and were identified to DOE as being inadequately supported in the Agency's letter of March 19, 1997 (Docket A-93-02, II-I-17). All but two of the 58 parameters were identified through the aforementioned screening of the 465 parameters included in the tables in Appendix C. The two additional parameters, 3405 SOLMOD6 - SOLCIM and 3409 SOLMOD6 - SOLSIM, represent uranium +6 solubility limits in Castile and Salado brines. The other SOLMOD parameters for actinide oxidation states +3, +4, and +5 had been retained by the screening. Because of this, the SOLMOD6 parameters were given a more detailed review and identified as also requiring additional evaluation.

The Agency found that the 58 parameters could be divided into three categories. These categories were identified in separate enclosures of the March 19, 1997 letter: (1) parameters lacking supporting evidence in Enclosure 2; (2) parameters that have records supporting values other than those selected by DOE in Enclosure 3; and (3) parameters that are not explicitly supported by the relevant data or information in Enclosure 4).

Of the 58 parameters, the Agency found that thirteen lacked supporting evidence, five had records supporting different values, and forty were not explicitly supported by DOE's information. These parameters were dispositioned by receiving adequate additional supporting documentation from DOE or through the Agency's studies, by determining that the PA results were not sensitive to the parameter through a sensitivity analysis conducted by the Agency, or by requiring the DOE to modify the parameter value, range, or distribution in a Performance Assessment Verification Test (PAVT) based on revised values, ranges, or distributions mandated by the Agency. The Agency's letters to DOE dated April 17, 1997 (Docket A-93-02, II-I-25) and April 25, 1997 (Docket A-93-02, II-I-27) document the final disposition of these parameters as summarized below. A detailed discussion of the disposition of these 58 parameters is presented in the Technical Support Document for Section 194.23: Parameter Justification Report (Docket A-93-02, V-B-14).

DOE provided the Agency with additional documentation to support its parameter values in response to EPA's March letter during various meetings at SNL from March, 1997 to May, 1997. This additional documentation is stored at the SNL Nuclear Waste Management Records Center in Albuquerque, New Mexico and is documented in DOE various response letters (Docket A-93-02, II-I-02 through II-I-38). The Agency found that this information adequately supported 19 of the 58 targeted parameters, and DOE was informed in the Agency's aforementioned April 17, 1997 and April 25, 1997 letters that those parameters were no longer in question.

Upon review of DOE's additional documentation, the Agency found that DOE was using a different definition of "professional judgement" than the Agency. DOE considered a parameter to be based on professional judgement if the judgement of SNL personnel played a significant role in interpreting available data when determining a parameter value. The Agency considered a parameter to be based on professional judgement if no data were available and judgement played an exclusive role in determining a parameter value. To clarify this difference, the Agency requested DOE to provide additional documentation on its "professional judgement" parameters,

to determine whether they should be based on a formal expert elicitation process. This request was documented as Issue 7 in Section 5.3 below.

The Agency conducted a sensitivity analysis on most of the 58 parameters to determine if changing the parameter values would have a significant impact on the PA model results (see Docket Technical Support Document for Section 194.23: Sensitivity Analysis Report, Executive Summary). The Agency found that 27 of the 58 parameters have a significant impact on results and that 31 of the 58 parameters did not have a significant impact. Some of these parameters, both with and without significant impact, were the same as those considered to be no longer in question on the basis of additional documentation. Based on the sensitivity analysis results alone, 20 parameters were considered to be no longer in question based on low sensitivity and 5 parameters were required to be changed in the PAVT because of model sensitivity and lack of adequate justification. Five parameters were considered to be no longer in question because they were found to not have been used in the 1996 CCA PA or were eliminated because of Agency-approved model changes, but three new parameters were added to those to be changed in the PAVT to achieve the Agency's intended objectives.

The Agency did not agree with the technical justification for some parameters. The Agency could not find documentation to support one of DOE's "professional judgement" parameters and considered it to be an expert judgement parameter, the particle diameter value used in the CUTTINGS_S computer code to calculate the spalling release. This parameter was identified as potentially important to PA and was required in the Agency's letter of April 25, 1997 to be developed by expert elicitation (see Docket A-93-02, II-I-27). The remaining DOE professional judgement parameters were found to have adequate technical support and did not require expert elicitation (see Appendix SR). Ten parameters were considered by the Agency to not be appropriately justified, sometimes despite the sensitivity analysis results, and were included as requiring changed values in the PAVT. After making the necessary adjustments to allow for model changes, a final list of 22 parameters were identified to be changed in the PAVT. Tables summarizing the disposition of the 58 parameters and identifying the new parameters are presented in the Technical Support Document for Section 194.23: Parameter Justification Report (Docket A-93-02, V-B-14, Tables ES-1 through ES-4).

5.3 Identification of Issues

During this more detailed technical screening, issues arose that were addressed through a series of questions or flags. The issues identified include examples where parameters were based on empirical information and had not been verified by experimentation or testing, where parameters were treated as constants in the CCA that could arguably be better defined as sampled distributions, and examples where the same values were applied to multiple analog parameters (such as directional permeabilities). These issues were subjected to a systematic process of focusing the review on those parameters that have significant impact on PA results. When reviewing distribution type selection, the parameter review team would evaluate whether SNL followed their own internal directives. The parameter review team also evaluated whether the selection was valid from the perspective of broader general research practices, whether the range of values was too broad (based on field, laboratory or literature information) to justify use of a constant value in the CCA PA, and whether use of important data values in the CCA PA was arbitrarily minimized by the selected parameter distribution.

The applicability of the statistical distributions selected by DOE for sampling parameter values in the CCA PA and the documentation of the methods used to define those distributions (including literature, field data, laboratory data, and peer review) were important elements of the review. Relative to the sampling distributions, it was considered critical to flag those parameters for which the selected distribution was poorly supported in the available record. However, a poorly supported distribution was not necessarily construed as determining that the parameter value itself was inadequate. The adequacy of the distribution was one of the factors used by the Agency in identifying the inadequately supported parameters.

Another concern was that some parameters of interest, such as those related to fracture permeabilities for Anhydrite A/B and Marker Beds 138 and 139, were not discretely available at the time of the initial parameter review. In the marker bed example, the fracture permeability was derived using a model configuration based on parameter elements that were presented as constants for which a sample distribution could be more appropriate (parameters 2811 and 2178). As a result, there was no discrete parameter package to review and it was unclear what the derived value was and whether it was comparable to data that could be derived at the site or that may be available from industry or academia. Nor was it clear how key associated information or parameters were developed that were presented as constants, such as the fracture initiation pressure increment (parameter 586) and incremental pressure for full fracture development (parameter 2180). Some of these parameters were included among the 58 parameters identified to DOE as requiring further evaluation. The concerns were ultimately resolved when DOE provided documentation that appropriately supported these parameters (Docket A-93-02, II-I-24).

An assessment of the parameter's potential impact on radionuclide transport predictions was a key issue addressed during these reviews, recognizing that such an assessment was clearly a preliminary judgement of the parameter review team. At this stage of the review, field and laboratory data were necessarily reviewed only in summary form. No effort was made at this stage to verify laboratory or field data acquisition procedures in a formal manner. In addition, at this time the parameter review team identified parameter documentation that appeared inconsistent and needed better organization and traceability.

The review also evaluated analogy assumptions by highlighting those areas where, in the parameter review team's view, analogies were being drawn on too broad a set of materials or too broad a time frame than is technically justifiable. For example, the parameter review team questioned whether it was reasonable to apply single parameter values to materials as diverse as clays, sands, concrete, and asphalt, or whether it was appropriate to apply constant parameter values over long time periods with no recognition of the changes in state expected to occur. In addition, parameters were flagged where unwarranted judgement may have been applied by the PI in the absence of hard in situ data or literature sources. There was concern over this issue if, for a given parameter, the PI's judgement was not also supported by an independent Peer Review.

Many of these issues were resolved during the Stage III review. However, the seven key issues discussed in the following paragraphs were identified for later resolution. Resolution of these issues is documented in Attachment SR to this report.

Issue 1: Complete the Comprehensive Database of all Parameters Used in the WIPP CCA Performance Assessment. During the course of the Agency’s review, additional CCA PA model parameters were identified and reviewed that were not included in the original database prepared by SNL during Stage I. Legacy parameters adopted from the earlier 1992 Performance Assessment are examples of parameters that were not all included and are discussed further under Issue 6 below. To resolve this issue, SNL revised the database presented in Appendix A of this report.

Issue 2: Develop a Database of all Performance Assessment Parameters that are Based on Empirical Data. Empirical data are data based in whole or in part on observations that have not been verified by experimentation or testing. CCA PA parameters based on empirical data were generally not supported by documentation detailing their source, the quality of the underlying basis, and the development of the PA parameter value from the empirical information. To resolve this issue, SNL identified and developed a supporting database for the most critical of the 465 parameters identified in Stage II of the Agency’s parameter review that were based on empirical data.

Issue 3: Improve the “Roadmaps” that Link Parameter Values Used in the CCA to their Sources. The parameter review team found varying degrees of traceability for the parameters. A need for more precise parameter roadmap documentation on Form 464 was recognized by all reviewers. Many existing Form 464s did not provide specific information on how to find critical support data packages. The reviewers found that the degree of parameter complexity often correlated with the inadequacy of the available Form 464; the more complex the parameter, the less adequate the roadmap. Also, while many of the Parameter Record Packages provided roadmaps, the referenced documents did not always provide a clear summary that explained the parameter’s development from field or experimental data to final CCA PA parameter values. Similarly, a consistent, definitive connection was seldom found between the findings of a Peer Review of general science/engineering categories and the specific application of those findings to a given parameter value. The Parameter Record Packages typically identified, at best, a Peer Review occurrence with no tie to actual results. To resolve this issue, SNL prepared a Parameter Guidebook (WPO# 47127) that contains, among other information, the necessary roadmap documentation for the most critical of the 465 parameters identified in Stage II of the Agency’s parameter review.

Issue 4: Integrate the Record Parameter Information that was Produced by SNL Personnel in March 1997 into the Official Parameter Records. In response to the Agency’s letter of March 19, 1997 (Docket A-93-02, II-I-17), DOE provided the Agency with additional documentation to support its parameter values. This issue primarily relates to the approximately 18 parameters that the Agency questioned as being based solely on judgement. Some of this documentation was new and had not been entered into the official parameter records. To resolve this issue, SNL assigned WPO numbers to these documents to ensure their traceability to the appropriate Form 464s.

Issue 5: Document Legacy Parameters. Legacy parameters are CCA PA parameters that were used in the 1992 Performance Assessment and were incorporated without change into the 1996 CCA PA. During the Stage II review, the parameter records addressing legacy parameters were

generally found to not adequately discuss the origin of these values. In some cases, such as the DRZ parameters, significant data sets have been compiled that could provide the necessary support. To resolve this issue, SNL provided complete traceability of legacy parameters.

Issue 6: Provide Documentation to Justify that the Approximately 149 Parameters Previously Classified as being Based on Professional Judgement by SNL do not Require Expert Elicitation. The parameter review team found a number of cases where parameters appeared to be developed based solely on the professional judgement of the principal investigator or other SNL personnel and had not been subjected to a formal expert elicitation process. Also, because of inadequacies in traceability, it was often difficult for the parameter review team to determine which parameters were based on professional judgement or expert judgement. In 40 CFR 194.26, the Agency requires that parameters based exclusively on expert judgement be developed through a formal expert elicitation process. The Agency's use of expert judgement is not equivalent to DOE/SNL's definition of professional judgement. Section 194.26, states that expert judgement is to be used if "data cannot be reasonably obtained through data collection or experimentation". SNL confused the issue of the application of expert judgement and professional judgement for some of the CCA PA parameters. SNL's definitions of professional judgement is that judgement is used when SNL staff interprets information in the literature or experiments conducted by SNL or others. For example, judgement is used to calculate the anhydrite permeability from multiple measurements. The Agency believes that DOE/SNL appropriately used judgement on existing information except for the size of the particle diameter. To resolve this issue, DOE/SNL documented that the subject parameters were not based solely on professional judgement.

6.0 STAGE IV REVIEW: DATA RECORDS PACKAGE REVIEW

Selected Data Record Packages were reviewed by the parameter review team in Stage IV to evaluate the traceability of the values of key parameters that were based on field or laboratory measurements, and the use of DQCs in the data collection process. For parameters based on laboratory or field data, the Principal Investigator Record Package generally contained a summary of the data used to develop the parameter value as well as a description of how the data were interpreted. During Stage IV, the data values summarized in the Principal Investigator Record Package were traced to the supporting Data Record Package. The Data Record Packages were reviewed with the goal of identifying the quality of the basic field and laboratory measurements. The parameter review team recognized that much of the database was developed prior to 194.22 requirements being established for the WIPP Program. Thus the parameter review team did not follow a customary audit protocol but instead developed the review template “Technical Review of Data Packages” for summarizing the different aspects of quality that might be found in a given data record package.

Approximately 23 parameters listed under the laboratory/field data column in Appendix C were selected for review to determine whether the parameter values could be adequately traced to their source measurements, whether the basis for the parameter values was clearly documented, whether the source measurements were adequately qualified by approved QA programs or by a Qualification of Existing Data (QED) process, and whether the documentation provided evidence of an awareness of the need for quality measures by citing DQCs. The 23 reviewed parameters were selected based on potential importance to PA and to provide a sampling of the measured parameters used by DOE to support the CCA PA. An awareness of the need for quality in laboratory and field data collection programs was evident throughout the documentation. Most of the parameters were supported by QA programs and evidence of DQCs was present in all Data Record Packages and data reduction documents. Those data that had not been collected under approved QA programs were supported by QED processes. Eleven of the 23 parameters were reviewed in February 1997, and the remaining parameters were reviewed in September 1997 to assess DOE’s continuing efforts to improve parameter documentation. Most parameters were found to be well documented and traceable, with consistent exceptions being found only in documenting the specific basis for selecting the type of statistical distribution. The information collected in these reviews is presented in Appendix D.

Figure 5 presents a completed Data Record Package review template using Castile brine pressure (Parameter 66: CASTILER - PRESSURE) as an example. This example is indicative of the approach and level of detail that this review step entailed. The process followed in the review of this parameter is described below in sufficient detail to provide insight into the activities undertaken by the parameter review team throughout the parameter review process.

The laboratory/field data review for the Castile brine pressure example built upon the technical review conducted under Stage II. It began by again requesting the Form 464, which was known to be WPO # 31612A from the parameter review team’s previous review, to identify the documents containing the raw laboratory/field data. This Form 464 presents the parameter distribution and in turn, identifies WPO # 31072 as the Parameter Record Package. The Parameter Record Package was then requested. It indicates the data were qualified by a Peer Review, as documented in the Peer Review Report (WPO # 41247) which states that the data are “adequate.” The Parameter Record Package gives several references for data interpretation: the TME-3153 report and SNL

Reports SAND92-0700/3, SAND89-7069, and SAND89-0462. The Parameter Record Package did not give the title of the data package; rather, a placeholder statement was given (“will be provided at a later date”). The cited documents were then reviewed to see if they contained the raw data or provided references to the raw data. The SNL reports referenced the TME-3135 report as the source of the data. The TME-3135 report presented a summary of brine pressure data for 13 boreholes: two of these boreholes had been tested by SNL (ERDA-6 and WIPP-12), eight had been tested by oil drilling companies, and the remaining borehole data were from previous studies by others.

The TME-3135 report contained a reference to the raw data for the two boreholes investigated by SNL (WPO # 42624: Data File Report ERDA-6 and WIPP Testing). The TME-3135 report referenced the TME-3080 report as the source of the data for the eight boreholes investigated by the oil drilling companies. WPO # 42624 was then reviewed to verify the data values summarized in the TME-3135 report and in the Parameter Record Package for the two boreholes investigated by SNL. The ERDA-6 data are in Appendices IIIA and IIIB of WPO # 42624, and the WIPP-12 data are in Appendices IVA and IVB. The measurements for each borehole include a range. The testing methods and descriptions given in WPO # 42624 appear to directly correspond with the methods and descriptions presented for the two boreholes in the TME-3135 report. However, discussions describing how these measurement ranges were aggregated into one number for each borehole could not be located. WPO # 42624 also describes a general Quality Assurance Program for collection of the data, provides specifications for the equipment used, and contains information regarding instrument calibration.

The parameter review team did not attempt to trace the borehole data for the remaining boreholes to the raw data, because these boreholes were investigated by non-SNL entities. The parameter review team did confirm that the data presented in the TME-3135 report accurately reflected the data presented in the TME-3080 report for the eight boreholes investigated by oil drilling companies. In summary, the parameter review team was able to trace the laboratory/field data presented in the Parameter Record Package to the raw data collected by SNL. However, the approach taken to reduce the raw data to one value for each borehole was not determined. Based on the documentation, the parameter review team was able to determine how the data were qualified and was able to review documentation regarding quality assurance plans, equipment specifications, and calibration methods. On this basis, although some of the Castile brine pressure data may not have been taken under an NQA-1 Quality Assurance Program, the values were deemed technically reasonable and useable in performance assessment.

The degree to which a causal relationship could be identified between laboratory/field data and parameter development varied. For some parameters a direct relationship was documented, while others were related indirectly by a discussion of how the parameter values were derived based on interpretation of a variety of data and sources but with little clear explanation of the interpretive logic. In some cases, no traceability or quality characteristics were documented to establish an acceptable parameter/data package relationship. The results of this review were used by the Agency in dispositioning the 58 parameters identified to the DOE in the Agency’s March 19, 1997 letter (Docket A-93-02, II-I-17) as being inadequately supported. The disposition of those parameters is described in the Technical Support Document for Section 194.23: Parameter Justification Report (Docket A-93-02, V-B-14).

7.0 RESULTS AND CONCLUSIONS

Following an interactive screening process, the Agency identified 1,571 parameters used in the CCA PA and found after reviewing the DOE's supporting documentation that 58 of those parameters were potentially important to performance assessment and were not adequately supported. These parameters are listed in Table 1 and were identified to DOE as being inadequately supported in the Agency's letter of March 19, 1997 (Docket A-93-02, II-I-17). The Agency found that the 58 parameters could be divided into three categories. These categories were identified in separate enclosures of the March 19, 1997 letter: (1) parameters lacking supporting evidence in Enclosure 2; (2) parameters that have records supporting values other than those selected by DOE in Enclosure 3; and (3) parameters that are not explicitly supported by the relevant data or information in Enclosure 4). These parameter categories are discussed in the following paragraphs.

7.1 Parameters Lacking Supporting Evidence

The thirteen parameters or parameter groups listed in Table 1 Section A were identified to the DOE as lacking supporting evidence and were therefore poorly justified. Summary discussions supporting these designations are presented in Appendix E. Additional details are provided in the Technical Review Sheets in Appendix B.

7.2 Parameters that have Records Supporting Values other than those Selected by DOE

Five parameters were identified for which the record supports values other than those selected by DOE/SNL the CCA PA and are listed in Table 1 Section B. Discussions of the basis for identifying each of these parameters are presented below. Expanded discussions of the file material and the review steps are provided for the first two parameters to provide a logic for how this designation was applied. Additional details are provided in the Technical Review Data Sheets in Appendix B.

7.3 Parameters Not Explicitly Supported by the Relevant Data/Information

Forty parameters were identified that were not explicitly supported by the relevant parameter packages and are listed on Table 1 Section C. A discussion of the parameter review team's investigation of the Castile brine pocket pressure and the rationale for including that parameter in this group is provided below. This discussion is intended to supplement the discussion of this parameter previously presented in Section 6. Additional information on the parameters in this group may be obtained from the Technical Review Data Sheets presented in Appendix B.

Using Castile brine pocket pressure as an example, an explanation of the process used to identify that this parameter lacked sufficient supporting information for the form of its statistical distribution is presented below. Based on a review of the reference tables available by material number ID and material/parameter names (see CCA Docket A-93-02, II-G-I, Volume XI, Appendix PAR, Table 10), the parameter review team identified WPO # 31612A as the appropriate Form 464. This form presented the parameter distribution and in turn identified WPO # 31072 as the Parameter Records Package. WPO # 31072 documented the collection of eight data points that were the basis for the distribution. The form of the distribution was estimated from drilling and/or testing in boreholes that encountered brine reservoirs in the

Castile anhydrites. The Parameter Record Package identified WPO # 37148, a 3/20/96 memo from Freeze and Larson to Tierney, that documented a change in parameter values due to the consideration that the previous value was unduly conservative and inconsistent with available evidence.

The Parameter Record Package also identified several other WPOs of interest. WPO # 42568 was a 12/4/96 memo from Martell to Clather that provided additional documentation to be added to Form 464. WPO # 42622 was a 12/6/96 memo from Martell to Jon that presents verification of technical review calculations as indicated by the signature of the reviewer on the calculation worksheet. WPO # 38386 was a 6/12/96 memo of record from A. Lappin that documents the submittal of information to DOE Engineered Systems Peer Review Panel for their review and qualification. WPO # 37973 was a 5/20/96 memo from Freeze and Larson to the record that documents changes in the values assigned as the minimum and maximum for the parameter. A traceability evaluation criterion of 3 was applied to this parameter, recognizing the high degree of completeness and traceability of the data package to the PA. Relative to professional judgement, an evaluation criterion of 1B was applied indicating that while the values were justifiable, there were gaps in the documentation. In particular, the parameter review team expressed concern regarding the change in the distribution range without appropriate justification presented in the files. Because of its potential importance to PA and a lack of support for selecting the distribution, the parameter was included in the Agency's letter of March 19, 1997 Enclosure 4 as requiring additional evaluation (Docket A-93-02, II-I-17).

7.4 Remaining Issues

Most of the information required by the Agency to complete its review of the CCA PA database was found within the documentation provided by DOE/SNL. However, at the end of the parameter review team's initial activities, significant issues related to parameter development and support documentation were still outstanding. These issues were identified during Stage III activities and are discussed in Section 5 of this report. Following is a summary listing of the issues. These issues were subsequently addressed in an adequate manner by SNL, and their resolution is documented in Attachment SR.

Issue 1: Complete the Comprehensive Database of all Parameters Used in Basic WIPP Performance Assessment.

Issue 2: Develop a Database of all Performance Assessment Parameters that are Based on Empirical Data.

Issue 3: Improve the Roadmaps that Link Parameter Values Used in the CCA to their Sources.

Issue 4: Integrate the Non-official Record Parameter Information that was Produced by SNL Personnel in March 1997 into the Official Parameter Records.

Issue 5: Document Legacy Parameters. Legacy parameters are CCA PA parameters that were used in the 1992 Performance Assessment and incorporated without change into the 1996 CCA PA.

Issue 6: Provide Documentation to Justify that the Approximately 149 Parameters Previously Classified as being Based on Professional Judgement by SNL do not Require Expert Elicitation.

The parameter review team's work reflects the state of the DOE/SNL parameter documentation at the time of the review. During the period of the review, the documentation for many of the parameters was being updated both because of the team's interaction with SNL and also due to SNL's ongoing process of updating the files. If the review had been conducted at a later date, documentation would be available for many parameters that was not available during the Agency's review. The DOE/SNL responses to the seven aforementioned Agency issues and the additional documentation provided for the parameters identified as being inadequately supported have considerably strengthened the parameter documentation.

FIGURES AND TABLE

Figure 1. - Parameter Documentation Process

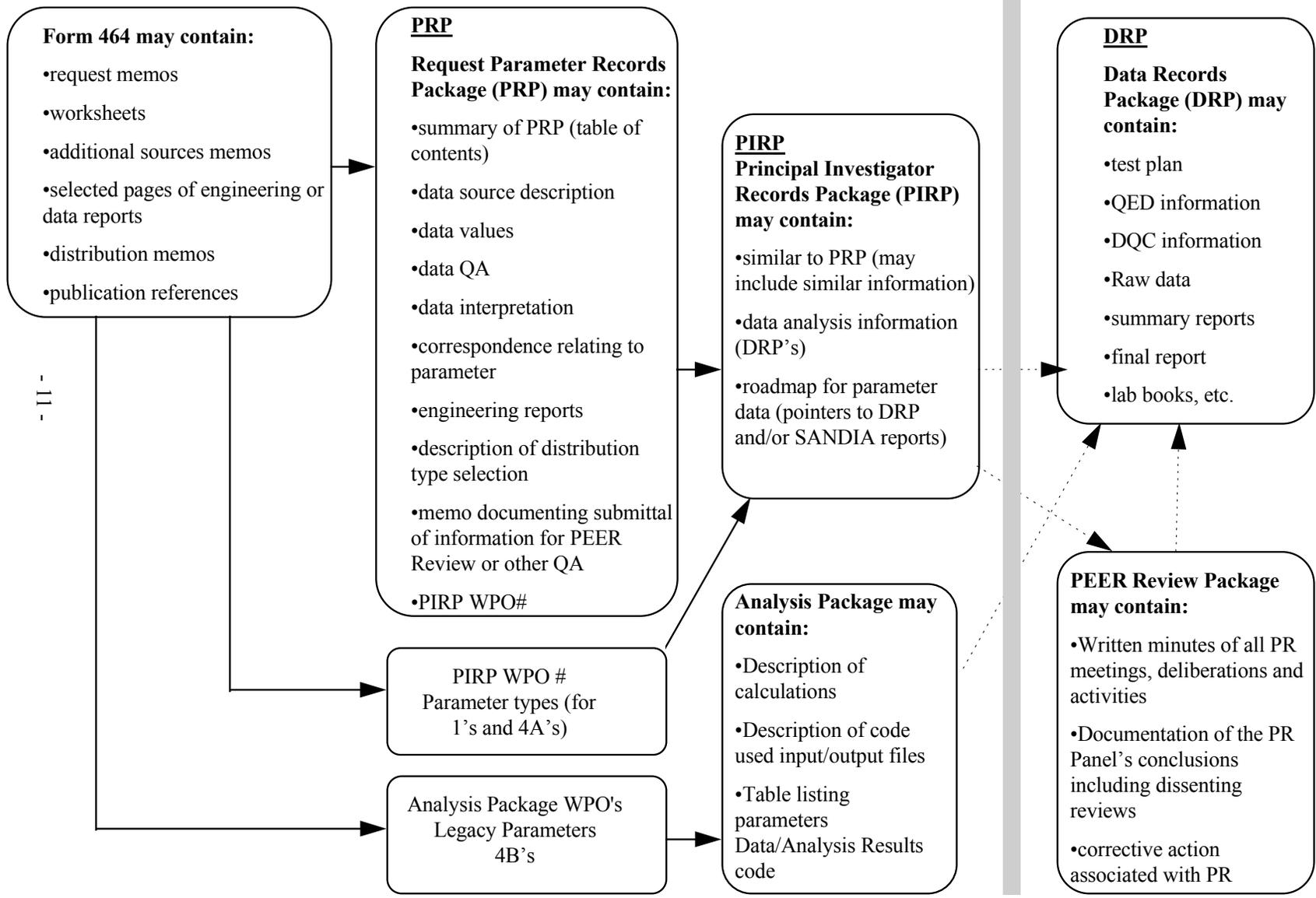


Figure 2. - Data Base Parameter Data Sheet

id	Parameter in Database? (Y/N)	If the values used in CCA are not the same as in DB, provide % difference (footnote 1)	Material Id	Material Name	Parameter Id	Parameter Name	PRP ID (WPO#)	Data Entry Date	Is the 464 consistent with the parameter in the database? (Y, N/A)	Parameter category (footnote 2)	Classification of Data Category (footnote 3)	Professional Judgment Development Code (footnote 4)	Distribution Type	mean	median

Footnotes

Parameter Variability from CCA

¹ If the value of the parameter was calculated based on the value of one or more other parameters, "calculated" appears in this column. Refer to the "If the values used in CCA are not the same as in Database, what is the value?" column for a description of the calculation.

² Parameter Category Descriptions

- 1 Parameters based on site specific information used as initial input to a WIPP numerical model
- 2 Parameters representing the inventory of the waste to be emplaced in the WIPP as defined in the BIR
- 3 Parameters representing precisely known, tabulated physical constants
- 4A Parameters that are assigned based on a similarity of properties between similar material or features
- 4B Parameters that are model configuration parameters not based on specific WIPP properties or features, but are necessary to make PA models run
- 5 Parameters not used in the current compliance calculations

³ Classification of Data Used in Development of Parameters

- 1 Site-specific or waste-specific experimental data
- 2 Waste-specific observational data
- 3 Professional judgment
- 4 General literature data
- 5 General engineering knowledge

⁴ Professional judgment development code:

- 1A Well Documented, Technically Justifiable
 - 2A Well Documented, Some Technical Questions
 - 3A Well Documented, Technically Inadequate
 - 1B Not Well Documented, Technically Questionable
 - 2B Not Well Documented, Some Technical Questions
 - 3B Not Well Documented, Technically Questionable
- Note: This classification was determined for only highlighted parameters. Highlighted parameters were included in the technical review of parameters.

⁵ Methods Used to Qualify Existing Data

- 1 Peer review
- 2 Corroborating data
- 3 Confirmatory testing
- 4 Demonstration that the data were collected under a Quality Assurance Program equivalent to NQA-1/3
- 5 If none of the above methods were used, then the data remains qualified
- 6 Non-WIPP published literature: journal articles, conference papers, text books, hand books, etc.
- 7 QED (same as 4 above)

⁶ Traceability from the parameter to the data source code:

- 0 No documentation found in files to support parameter development.
 - 1 Primary data source packages are referenced; however, data in the primary data source packages are not consistent with values in the database or the non-database parameters values.
 - 2 Primary data source packages are incomplete and some elements and logic are not traceable from the parameter database or non-database parameter values to the primary data sources.
 - 3 Primary data source packages are complete and the parameters are traceable from the parameter database or non-database parameter values to the primary data sources.
- Note: This classification was determined for only highlighted parameters. Highlighted parameters were included in the technical review of parameters.

⁷ The value given in the CCA database for Parameter ID #3148 was not the value used in the modeling, according to the CCA Model QA Team. This difference was not identified by Sandia in the "CODE_

Figure 5. - TECHNICAL REVIEW OF DATA PACKAGES

Page 1 of 4

Parameter ID#: 66 Material Name: CASTILER Property Name: PRESSURE

Data Package Traceability:

	Well Documented	Partially Documented	Poorly Documented	Comments
Data Source Documents	X			Measurements at 13 boreholes were used; however, only two of the boreholes were from measurements taken by Sandia. The documentation traced to the two boreholes (ERD-46 and WIPP-12) for which Sandia investigated and 8 boreholes investigate by several oil drilling companies. The remaining borehole data were from previous studies. The citations for these data were not given.
Parameter Value(s)		X		The measurement values are given in Table H-1 of WPO #42085 and the measurements for ERDA-6 and WIPP 12 trace to WPO #42624. However, it is unclear how the measurements from WPO 42624 were then used to develop the values in WPO #42095. The values for the oil company boreholes are traceable to WPO #42635.
Internal Traceability of Data Source Documents	X			Documents are traceable from one to another.

Specifications:

	Description		Compliance Information		Comments
	Cited? (Y/N)	WPO No. of Citation	Cited? (Y/N)	Description/ WPO No. of Citation	
Test Plan	N				
QAPP	Y				Appendix F of WPO #42624 describes Quality Assurance Procedures for laboratory work, but not for the hydrologic work; however, "all field procedures... were audited by quality assurance personnel to check that proper quality control procedures were being followed..."
ASTM Standards	N		N		
Other:					

Technical Reviewer: K. Cornils/J. Darabaris/ P. Kelly Date: 2/20/97

Figure 5. - TECHNICAL REVIEW OF DATA PACKAGES

Page 2 of 4

Parameter ID#: 66 Material Name: CASTILER Property Name: PRESSURE

Qualification of Existing Data:

Description	WPO No.	Comments
Peer Review	PEER-Review	Considered adequate. A copy of the results from WPO #41247 is attached. The panel stated that the data collection and interpretation processes cover the “spatial variability of the pressure, and... present the most likely pressure associated with a high probability, based on existing data.”
Corroborating Data		
Confirmatory Testing		
Other: <u>QAP 9-5</u> .	42622	A technical review for the distribution calculations was completed.

Data Values:

Description	WPO No.	Comments
Raw Data Values	42624	ERDA-6 data are in Appendices IIIA and IIIB. WIPP-12 data are in Appendices IVA and IVB. The measurements for each borehole include a range. There appears to be no discussion describing how these ranges were aggregated into one number for each borehole (e.g., by calculating the average), as Table H-1 of WPO #42085.
Data Reductions/Calculations	31072 SAND92-0070	The interpretation of the data and final estimate of the range for this parameter appears to be well documented in these sources.
DQC Information	42624	Appendix E provides detail of the downhole and surface testing instrumentation for the drill stem testing in ERDA-6, including calibration data and instrument specifications, and the specifications for the various flow meters used in WIPP-12.
Measurement Control	42624	Appendix F states that “calibration records were inspected for hydrologic testing and field laboratory equipment” for WIPP-12, Additional information is provided in Appendix B.
Other: _____.		

Technical Reviewer: K. Cornils/J. Darabaris/ P. Kelly Date: 2/20/97

Figure 5. - TECHNICAL REVIEW OF DATA PACKAGES

Parameter ID#: 66 Material Name: CASTILER Property Name: PRESSURE

List of Data Source Documents:

No. of Source	WPO No.	Title	Reviewed by technical reviewer? (Y/N)	Traceability		Availability	
				Identified through Form 464 and/or supporting documents? (Y/N)	If no, how identified?	In Sandia Records Center? (Y/N)	If no, where located?
1	31072	Castile Brine Reservoir Pressure	Y	Y		Y	
2	31612	Form 464	Y	Y		Y	
3	35268	Distributions	Y	Y		Y	
4	35597	Request Memo	Y	Y		Y	
5	37148	Initial Pressure in the Castile Brine Reservoir	Y	Y		Y	
6	37973	Castile Brine Reservoir Pressure Record Package	Y	Y		Y	
7	38386	Qualification of Data, Calculations, and/or Interpretations Contained in the PRP	Y	Y		Y	
8	42085	Brine reservoirs in the Castile Formation, WIPP, TME 3153	Y	Y			
9	42568	Additional Information for the Permeability Parameter	Y	Y		Y	
10	42622	Signatures on 464's and Attachments for Technical Verification According to QAP 9-5	Y	Y		Y	
11	42635	Brine Pocket Occurrences in the Castile Formation, SE NM, TME 3080	Y	Y		Y	
12	42624	Data File Report ERDA-6 and WIPP-12 Testing	Y	Y		Y	
13	SAND89-0462	Systems Analysis, Long-Term Radionuclide Transport, and Dose Assessments, WIPP, SE NM	Y	Y		Y	

Figure 5. - TECHNICAL REVIEW OF DATA PACKAGES

Parameter ID#: 66 Material Name: CASTILER Property Name: PRESSURE

14	41247	WIPP Natural Barriers Data Qualifications Peer Review Report	Y	Y		Y	
15	SAND92-0700/3	Preliminary Performance Assessment for the WIPP, December 1992	Y	Y		Y	
16	SAND89-7069	Regional Double-Porosity Solute Transport in the Culebra Dolomite Under Brine-Reservoir-Breach Release Condition: An Analysis of Parameter Sensitivity and Importance	Y	Y		Y	

Additional Discussion:

Table 1. Inadequately Supported Parameters Identified in EPA's March 19, 1997 Letter

<u>Parameter No.</u>	<u>Material ID - Parameter ID</u>	<u>Parameter Description</u>
A. Parameters Lacking Supporting Data (Enclosure 2 Parameters)		
1	3245	BLOWOUT - CEMENT Waste Cementation Strength
2	3246	BLOWOUT - PARTDIA Waste Particle Diameter
3	198	DRZ_1 - PRMX_LOG DRZ Permeability
4	2177	S_MB_139 - DPHIMAX Incremental Increase in Anhydrite Porosity in MB 139
5	2180	S_MB_139 - PF_DELTA Incremental Pressure for Full Fracture Development
6	586	S_MB_139 - PI_DELTA Fracture Initiation Pressure Increment
7	2178	S_MB_139 - KMAXLOG Maximum Permeability in Altered Anhydrite
8	3134	BH_OPEN - PRMX_LOG Open Borehole Permeability
9	2158	S_ANH_AB - DPHIMAX Incremental Increase in Anhydrite Porosity in Beds A and B
10	214	EXP_AREA - PRMX_LOG Experimental Area Permeability
11	3473	BLOWOUT - THCK_CAST Thickness of Castile Brine Pocket for Direct Brine Release
12	3456	BLOWOUT - RE_CAST Radius of Castile Brine Pocket for Direct Brine Release
13	2918	CASTILER - GRIDFLO Index for Selecting Brine Pocket Volume
B. Parameters with Different Values or Ranges (Enclosure 3 Parameters)		
1	3493	GLOBAL - PBRINE Probability of Encountering Pressurized Brine
2	2254	BOREHOLE - TAUFAIL Waste Shear Resistance
3	3184	BH_SAND - PRMX_LOG Long-Term Borehole Permeability
4	2918	CASTILER - VOLUME Castile Brine Pocket Volume
5	61	CASTILER - COMP_RCK Castile Brine Pocket Rock Compressibility
C. Parameters with Questionable Values or Ranges (Enclosure 4 Parameters)		
1	27	BOREHOLE - DOMEGA Drill String Angular Velocity
2	64	CASTILER - POROSITY Castile Brine Pocket Porosity
3	66	CASTILER - PRESSURE Castile Brine Pocket Pore Pressure
4	259	PAN_SEAL - PRMX_LOG Panel Seal Permeability
5	528	S_ANH_AB - POROSITY Effective Porosity of Anhydrite Beds A and B
6	567	S_MB138 - POROSITY Effective Porosity of Anhydrite MB 138
7	588	S_MB139 - POROSITY Effective Porosity of Anhydrite MB 139
8	651	WAS_AREA - ABSROUGH Waste Area Absolute Roughness
9	653	WAS_AREA - COMP_RCK Waste Area Rock Compressibility
10	1992	WAS_AREA - DIRNCCHW Bulk Density of Iron Containers in CH Waste
11	1993	WAS_AREA - DIRNCRHW Bulk Density of Iron Containers in RH Waste
12	2040	WAS_AREA - DIRNCHW Average Density of Iron-Based Material in CH Waste
13	2041	WAS_AREA - DCELLCHW Average Density of Cellulosics in CH Waste
14	2274	WAS_AREA - DCELLRHW Average Density of Cellulosics in RH Waste
15	2907	STEEL - CORRMCO2 Steel Corrosion Rate
16	3147	CONC_PLG - POROSITY Borehole Plug Porosity
17	3185	CONC_PLG - PRMX_LOG Borehole Plug Permeability
18	3256	BLOWOUT - FGE Gravity Scaling Factor
19	3259	BLOWOUT - APORO Waste Permeability in CUTTINGS_S Model
20	3429	PHUMOX3 - PHUMCIM Humic Colloid Proportionality Constant in Castile Brine
21	3471	BLOWOUT - MAXFLOW Maximum Period of Uncontrolled Borehole Flow
22	3472	BLOWOUT - MINFLOW Minimum Period of Uncontrolled Borehole Flow
23	3433	PHUMOX3 - PHUMSIM Humic Colloid Proportionality Constant in Salado Brine
24	3470	BLOWOUT - GAS_MIN DBR Cutoff Gas Flow Rate

Table 1. Inadequately Supported Parameters Identified in EPA's March 19, 1997 Letter (Continued)

<u>Parameter No.</u>	<u>Material ID - Parameter ID</u>	<u>Parameter Description</u>	
25	3317	PU - PROPMIC	Microbial Colloid Proportionality Constant for Plutonium
26	3405	SOLMOD6 - SOLCIM	U(VI) Solubility Limit in Castile Brine
27	3409	SOLMOD6 - SOLSIM	U(VI) Solubility Limit in Salado Brine
28	3402	SOLMOD3 - SOLCIM	Oxidation State +3 Solubility Limit in Castile Brine
29	3403	SOLMOD4 - SOLCIM	Oxidation State +4 Solubility Limit in Castile Brine
30	3407	SOLMOD4 - SOLSIM	Oxidation State +4 Solubility Limit in Salado Brine
31	3404	SOLMOD5 - SOLCIM	Oxidation State +5 Solubility Limit in Castile Brine
32	34-8	SOLMOD5 - SOLSIM	Oxidation State +5 Solubility Limit in Salado Brine
33	3311	AM - PROPMIC	Microbial Colloid Proportionality Constant for Americium
34	3482	AM+3 - MKD_AM	Matrix Partition Coefficient for Americium +3
35	3480	PU+3 - MKD_PU	Matrix Partition Coefficient for Plutonium +3
36	3481	PU+4 - MKD_PU	Matrix Partition Coefficient for Plutonium +4
37	3479	U+4 - MKD_U	Matrix Partition Coefficient for Uranium +4
38	3475	U+6 - MKD_U	Matrix Partition Coefficient for Uranium +6
39	656	WAS_AREA - GRATMICH	Gas Generation Rate due to Microbial Action under Humid Conditions
40	657	WAS_AREA - GRATMICI	Gas Generation Rate due to Microbial Action under Inundated Conditions

TECHNICAL SUPPORT DOCUMENT FOR §194.23 - MODELS AND COMPUTER CODES VOLUME 2 of 3 APPENDICES

**U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Radiation and Indoor Air
Center for the Waste Isolation Pilot Plant
401 M. Street, S.W.
Washington, DC 20460**

MAY, 1998

Technical support for this document was provided by S. Cohen and Associates, Inc. and/or its subcontractors under EPA Contract Number 68D70073.

APPENDIX A COMPUTER CODE EVALUATIONS

APPENDIX A1 FMT COMPUTER CODE EVALUATION

The Fracture Matrix Transport (FMT) code solves chemical equilibrium problems using the Pitzer activity coefficient formalism. The Pitzer approach is the most accurate method for calculating activity coefficients for ionic species under conditions of high ionic strength as found in the WIPP brines. The FMT model computes activities and concentrations of constituents in brine solutions based on thermodynamic data and Pitzer parameters from Harvie, Møller, and Weare and Felmy & Weare (Docket: A-93-02, II-G-1, Ref. #286 and Ref. #245) for the following major components; hydrogen, oxygen, sodium, potassium, magnesium, calcium, chlorine, sulfur, carbon, boron, bromine, chlorate, phosphorus. This database has been augmented to include data for Am(III), Th(IV), and Np(V) which are relevant to use of FMT at WIPP. Positions in the database exist for U(VI) species, but no data actually exist in the database for these species and

consequently the FMT code is not used to model uranium chemistry.

For implementation in the PA, the FMT code is used to calculate the concentrations of Am(III), Th(IV), and Np(V) from the solubilities of specified actinide solids under conditions of chemical equilibrium. The code is not actually used for transport calculations as might be implied from its name. The effects on chemical conditions caused by equilibrium with specific solid phases part of the database are also included in the FMT calculation scheme. This capability is important for determining the effects of specific reactions, such as between magnesium hydroxide and magnesium carbonates, that are expected to be important for controlling pH and CO₂(g) fugacity in the repository—i.e., parameters that strongly affect the solubilities of actinide solids. The FMT model is not used for calculating redox equilibria. Instead, actinides are specified to exist completely in a single oxidation state, i.e., Am(III), Th(IV), and Np(V). Using oxidation state analogies, the results for these actinides are extrapolated to Pu(III), Np(IV), U(IV), and Pu(IV).

EPA REVIEW

a) Any compliance application shall include:

a.1) A description of the conceptual models and scenario construction used to support any compliance application.

A fundamental precept of the representation of the repository environment in the performance assessment is that the actinide source term can be described by chemical equilibrium processes. The FMT code is a model of chemical equilibrium as applied to actinide chemistry that incorporates the Pitzer approach for calculating activity coefficients relevant to the high ionic strength conditions present in the Salado and Castile brines. This conceptualization is summarized in Appendix SOTERM (Docket: A-93-02, II-G-1, Volume XVII) and more detail regarding chemical equilibrium processes are provided in Docket: A-93-02, II-G-1, Ref. #302, Ref. #477, Ref. #479; Docket: A-93-02, II-G-3, Volume 6, User's Manual; Novak, et. al. 1995; and Bynum 1996.

In summary, the chemical equilibrium concept as applied to the repository environment involves the following assumptions:

- the system of brine and wastes is well-mixed (Appendix SOTERM)
- the brine composition entering the repository is constant with time

(Appendix SOTERM)

- the brines are in chemical equilibrium with the common minerals found in the Salado and Castile formations (e.g., halite and anhydrite) (Appendix SOTERM and Ref. #479)
- the brine pH (or pCH) and fugacity of CO₂(g) will be buffered to specific values by the equilibrium between brucite [Mg(OH)₂] and magnesite [MgCO₃] as a result of brine interactions with the MgO backfill material (Appendix SOTERM and Ref. #479)
- the concentrations of actinides released to the brines can be represented by the experimentally determined solubilities of the actinide-bearing solids expected to form under the prevailing solution conditions (Appendix SOTERM, Ref. #477, Ref. #479 and Novak, et. al., 1995)
- the effects of redox reactions can be adequately represented by assuming dominant valence states for the actinides expected to be stable under the reducing conditions of the repository, where reducing conditions are generated from the consumption of oxygen by decaying organic material and ferrous metals (Appendix SOTERM)
- oxidation state analogies can be used to represent the concentrations of actinides for which solid-phase solubility data are not available or inadequate, i.e., Am(III) is used to represent Pu(III), where Th(IV) is used to represent Np(IV), Pu(IV) and U(IV), etc. (Appendix SOTERM and Novak, et. al., 1995)
- solubility and aqueous speciation data are inadequate to model U(VI), hence a model solubility of 8.8×10^{-6} M (in Castile brine) is used to provide a conservative representation of expected U(VI) concentrations based on a variety of empirical measurements (Appendix SOTERM and Ref. #302)
- the uncertainty in predicted solubilities of actinide solids can be represented by the deviances between solubilities determined in individual experimental studies and concentrations predicted by models used to fit experimental data to aqueous speciation schemes (Appendix SOTERM, and Bynum 1996)
- the Pitzer approach provides the best representation of activity coefficient for the high ionic strength solutions found in the Salado and Castile brines (Appendix SOTERM, User's Manual, Ref. #477, Ref. #479, and Novak, et.

al., 1995)

a.2) A description of plausible alternative conceptual model(s) seriously considered but not used to support such application, and an explanation of the reason(s) why such model(s) was not deemed necessary to accurately portray performance of the disposal system.

A discussion of alternative approaches for calculating actinide concentrations is provided in Appendix SOTERM (pages 21-22) but the discussion is brief and lacking in details. Additional information is found in supplementary references, including ref. #477, Ref. #479, and Novak, et. al. 1995.

A number of geochemical models of equilibrium chemistry exist that may have been considered for calculating actinide concentrations from available solubility data rather than FMT, although these possibilities are not discussed in Appendix SOTERM. For the most part, these other geochemical models are applicable to low ionic strength solutions and cannot be considered applicable to the Salado and Castile brines. The implementation of alternative activity coefficient models, such as Harned's Rule and Specific Ion Interaction Theory are discussed in Appendix SOTERM, pages 22-23. However, the Pitzer approach as implemented in FMT using the databases of Harvie, Møller, and Weare and Felmy & Weare (Docket: A-93-02, II-G-1, Ref. #286 and Ref. #245) has been found to be more accurate than the other methods and directly applicable to the brine solutions of the Salado and Castile formations. Additionally, a well-tested database of Pitzer ion interaction parameters was already in existence from the work described in these same references that could be implemented directly in FMT.

Other geochemical models, including EQ3/6 and PHRQPITZ, exist that also contain algorithms based on the Pitzer approach and the cited databases for calculating activity coefficients under high ionic strength conditions applicable to the WIPP repository. These other models are not discussed in any detail in the references, although they were used for comparison of their calculation results to those from FMT in the Requirements Document & Verification and Validation Plan and the Validation Document for FMT (Docket: A-93-02, II-G-3, Volume 6). These alternative models have been in wider use in the scientific community than the FMT model, and EQ3/6 was developed primarily by the DOE for the high level nuclear waste program.

In another investigation, an expert panel was convened to define probable actinide concentrations that might be expected in the repository environment. Because of

uncertainties in chemical conditions, such as pH and CO₂(g) fugacity, this panel produced estimates of actinide concentrations ranging over many orders of magnitude based primarily on aqueous speciation and solubility data (Trauth, et. al. 1992 [Docket: A-93-02, II-G-1, Ref. #636] cited in Appendix SOTERM and Hobart, et. al. 1996 [Docket: A-93-02, II-G-1, Ref #304]). This range is probably too large to be meaningful. Since the time of the expert panel report, the use of an MgO backfill has been incorporated into the operation plan for WIPP. Reactions between the MgO and brines are expected to greatly narrow the range of chemical condition and consequently narrow the range of uncertainties in actinide concentrations calculated from solubility data.

Additionally, the possibility of measuring actinide concentrations directly in experiments designed to mimic waste/brine conditions expected in the repository is discussed in Appendix SOTERM, page 22, as an alternative approach. However, this approach is subject to numerous experimental difficulties, is extremely time consuming, and provides scant information on the potential long-term evolution of the brine/waste system. For these reasons, direct experimental studies were not considered to be practical as the primary source of predictive data for long-term actinide concentrations in the repository (*ibid.*).

a.3) Documentation that:

a.3.i) conceptual models and scenarios reasonably represent possible future states of the disposal system.

By definition, the thermodynamic approach used to calculate actinide concentrations under conditions of chemical equilibrium provides a depiction of the chemical state to which the disposal system should evolve over time (see FMT User's Manual and Appendix SOTERM for descriptions of the thermodynamic approach).

a.3.ii) mathematical models incorporate equations and boundary conditions which reasonably represent the mathematical formulation of the conceptual model.

To determine conditions of chemical equilibrium for a solid/solution system, the FMT model uses the criteria of minimization of free energy given the constraints of the chemical composition of the fluid in question and principles of mass and charge balance and mass action defined for individual chemical reactions (see FMT User's Manual). This method is entirely consistent with the definition of chemical equilibrium as being the state of lowest free energy. The equations of mass action and mass balance are defined in the thermodynamic database of the FMT model in

terms of specific reactions for aqueous speciation and solid phase solubility (see FMT User's Manual).

The FMT model was designed for application to high ionic strength solutions and contains algorithms that incorporate the Pitzer approach to calculating activity coefficients for dissolved species based on the databases developed in Docket: A-93-02, II-G-1, Ref. #245 and Ref. #286. These databases were developed for representing chemical equilibrium in the high ionic strength solutions found in evaporative lakes and are directly applicable to representing chemical reactions in the high ionic strength brines of the Salado and Castile formations.

a.3.iii) numerical models provide numerical schemes which enable the mathematical models to obtain stable solutions.

The FMT model uses the Villars-Cruise-Smith method to solve the system of linear mass balance and nonlinear equilibrium reactions that represent aqueous speciation and solid-phase solubility reactions for aqueous systems (FMT User's Manual). This method should produce stable and real solutions to problems that are well defined and do not contain phase-rule violations. The verification and validation studies described below indicate that the numerical schemes produce precise solutions when compared to criteria of mass balance and replication of equilibrium constants.

a.3.iv) computer models accurately implement the numerical models; i.e., computer models are free of coding errors and produce stable solutions.

A series of 9 verification and validation model runs or tests are described in the Requirement Document & Verification and Validation Plan (RD/VVP) and the Validation Document (VD) for FMT (Docket: A-93-02, II-G-3, Volume 6). These verification tests adequately cover the calculation limits of the FMT code used in the CCA PA. They are designed to test the ability of the FMT model to implement its numerical algorithms correctly and produce stable solutions.

The results from the first run verify that the FMT model correctly maintains mass balances for chemical components and accurately reproduces equilibrium constants (see VD, pages 198-208).

The second test indicates that the FMT model can reproduce the general effect of carbonate concentration on $\text{NaNpO}_2\text{CO}_3(\text{s})$ solubility, although the model calculation concentrations were generally lower than those measured in

experiments (see VD, pages 218-220).

The third test shows that FMT can reproduce the measured solubilities of various solids commonly found in evaporite deposits, such as the Salado and Castile formations, when compared to experimental measurements. These results indicate that the Pitzer ion interaction parameters of references 286 and 245 were entered correctly and provide accurate depictions of activity coefficients in high ionic strength solutions (see VD, pages 273, 276).

In the fourth test, results from FMT were compared with those obtained from EQ3/6 and PHRQPITZ, which are also models of chemical equilibrium with implementations of the databases of references 286 and 245. The FMT results are in very good agreement with those from the other models except for boron from the EQ3/6 model (see VD, pages 280-282). However, EQ3/6 did not contain a full boron model and boron is not considered to have any impact on actinide concentrations, hence the small discrepancies are not considered important.

The fifth test involved using FMT to titrate sulfate solutions with HCl to determine the effect on the solubility of AmPO_4 for comparison to experimental data and previous FMT calculations. The results show a very good match to the experimental data and replication of the FMT calculations used to represent AmPO_4 solubility in a previous FMT application.

In the sixth test, the criteria of mass balance was tested for an Am(III)-containing SPC (Salado) brine titrated with NaOH. Mass balances for oxygen and hydrogen were examined and found to match starting masses indicating that FMT's numerical solution scheme correctly satisfied the constraint of mass conservation in its calculation of equilibrium solution composition. Calculations of equilibrium constants for various speciation reactions also closely matched the values contained in the FMT database.

For the seventh test, results from FMT calculations were compared to Am(III) concentrations from solubility experiments with $\text{NaAm}(\text{CO}_3)_2 \cdot 6\text{H}_2\text{O}$ conducted over a range of carbonate concentrations. The comparison shows that FMT closely reproduces the solubility data, indicating that it provides an accurate representation of experimental results.

The eighth test case was directed at examining FMT calculations of the effects of elevated $\text{CO}_2(\text{g})$ fugacity on speciation of the SPC brine. The problem was run for a $\text{CO}_2(\text{g})$ fugacity of 60 atm and results were examined for mass balance violations.

The results showed that carbon and other elements were conserved.

In the ninth and final test, a number of test cases were run with input values that either represented physically impossible situations and incorrect chemical specifications. In all cases, the FMT code reported an error and stopped execution or produced a solution composition that reflected the errors in the input.

The verification and validation plan for the FMT code as described in the RD/VVP and the VD provides a clear indication that the FMT code provides correct and stable solutions for a variety of chemical equilibrium problems. The tests were appropriate, including checks of elemental mass balance, calculation of equilibrium constants, and comparisons of results with other geochemical codes. Additionally, FMT calculations of actinide-solid solubilities were in good agreement with experimental data. This test is important because FMT is used to calculate actinide concentrations from solubility data for input to the performance assessment.

The only test that was lacking in detail in the verification and validation study was directed at FMT's representation of CO₂(g) equilibria. However, additional execution of the FMT code, that has been conducted as part of other subsequent studies, indicate that FMT does provide accurate calculations of aqueous speciation and solubility in CO₂(g)-containing system (see below Section d). As a result, this issue is not considered to be a significant omission in the testing of the FMT code.

a.3.v) [conceptual models have undergone peer review according to § 194.27.](#)

The dissolved actinide source term, colloidal actinide source term, and chemical conditions conceptual models were reviewed by the Conceptual Models Peer Review Panel Documents. The Panel concluded that all these models were adequate for use in performance assessment (see Section 3 of the TSD(1) for details.)

b) [Computer codes used to support any compliance application shall be documented in a manner that complies with the requirements of ASME NQA-2a-1990 addenda, part 2.7, to ASME NQA-2-1989 edition. \(Incorporation by reference as specified in § 194.5.\)](#)

The FMT code is documented as specified in NQA-2a-1990 in the User's Manual, the Requirements Document & Verification and Validation Plan, the Validation Document, and the Implementation Document (Docket: A-93-02, II-G-1, Volume 5).

Although these reports describe the operation and testing of the FMT code, they do

not document the generation of the thermodynamic database used by FMT or the modifications to that database planned for the future. This issue is important because calculations of the solubilities of actinide solids with FMT are directly dependent on its thermodynamic database. This database has undergone continuous revision since the publication of the User's Manual and the CCA, and this has undoubtedly resulted in improvements, but the changes have made it difficult to reproduce past results exactly. For example, the database used for the verification studies is indicated to be `fmt_hmw_np_am.chemdat` in the Script file on page 29 of the RD/VVP, implying that it does not contain data for Th(IV). However, Table SOTERM-2 of Appendix SOTERM—which provides the calculated actinide concentrations from FMT for the CCA—concentrations are given for +IV actinides, i.e., Th(IV). Because Th(IV) is the model for the +IV actinides, a database distinct from that used in the RD/VVP and the VD containing data for Th(IV) species must have been used. Documentation of the history of changes in the FMT thermodynamic database and implementation for the CCA process is absent in the materials associated with the CCA. However, a complete copy of the data base was provided by Novak 1997.

c) Documentation of all models and computer codes are included as part of any compliance application performance assessment calculation shall be provided. Such documentation shall include, but not limited to:

c.1) Description of the theoretical backgrounds of each model and the method of analysis or assessment.

Theoretical aspects of the model construction are described in Section 4 of the User's Manual. Additional information is also provided in association with the results of the verification and validation model runs in the VD.

c.2) General descriptions of the models; discussions of the limits of the applicability of each model; detailed instructions for executing the computer codes, including hardware and software requirements, input and output formats with explanations of each input and output variable and parameter (e.g., parameter name and units); listings of input and output files from a sample computer run; and reports on code verification, benchmarking, validation, and quality assurance procedures.

A general description of the FMT code is provided in the User's Manual, including detailed instructions for executing the code. Lists of variable names are also provided in the User's Manual. Hardware and software requirements, input and

output formats with explanations of variables are also provided in the User's Manual with additional information in the RD/VVP and the VD. A series of listings of example input and output files are given in the User's Manual, and additional files are provided in the RD/VVP and the VD. Reports on code verification and validation are provided in RD/VVP and the VD, respectively.

The verification and validation study involved 9 test cases that cover the functional requirements of the FMT code. These tests were discussed above.

The UM, RD/VVP, VD and ID have all been subjected to internal peer review as indicated by quality assurance sign-off sheets attached to the references.

The FMT code was also tested for non-ANSI FORTRAN coding and uncalled modules by DECset SCA during testing. The results indicated no instances where the FMT code deviated from ANSI standard FORTRAN. Examination of the calling tree for modules indicated that none were isolated from the remainder of the code but were all implemented as needed. In the verification test cases, three modules were not exercised, including ACTBDT, EHCALC, and VSCHG, that are designed to calculate activity coefficients with the B-dot equation, oxidation potential, and surface charge, respectively. Because these implementations are not relevant to the actinide source term modeling for the WIPP PA, their lack of use in the test cases is not considered significant with regard to the CCA.

c.3) Detailed descriptions of the structure of computer codes and complete listings of the source codes.

The generalized structure of the file system and information flow for the FMT code is summarized in flow diagrams in the User's Manual (see Figures 1 and 2, page 23). A complete code listing for FMT is provided in the ID. However, the title of the ID refers to Version 2.1, whereas the code listing contained therein is for Version 2.0.

c.4) Detailed descriptions of data collection procedures, sources of data, data reduction and analysis, and code input parameter development.

The FMT code depends on a database of thermodynamic constants characteristic of specific reactions. Chemical potentials and Pitzer ion interaction parameters for the major elements included in the FMT database are based on the work of Harvie, Møller, & Weare 1984 and Felmy & Weare 1986 (Docket: A-93-02, II-G-1, Ref. #286 and Ref. #245) and their procedures for determining these constants are well documented. Constants for the actinides relevant to specific reactions described in

Appendix SOTERM are taken from a variety of sources published in the scientific peer-reviewed literature. As described in Appendix SOTERM, constants for the actinides were generated from fits to solubility data using the NONLIN program (Docket: A-93-02, II-G-1, Ref. #477, and WIPP PA 1996, cited in Appendix SOTERM). The NONLIN program contains the same database of Pitzer ion interaction parameters and chemical potentials as used by FMT so that internal consistency is maintained in the generation of new constants for inclusion in the FMT database. Details on the use of the NONLIN code are not provided in Appendix SOTERM of the CCA, but the reader is referred to the references above.

Although Appendix SOTERM identifies specific sources of thermodynamic data for the FMT code, it does not provide an indication of the specific database used for the performance assessment calculations presented in the CCA. Supplementary references cited in Appendix SOTERM also do not indicate which thermodynamic database was used for model calculations of actinide concentrations for the performance assessment as presented in Table SOTERM-2 of Appendix SOTERM. The database has undergone continuous revision since the CCA, which has probably resulted in improvements in its values and completeness, but has apparently obscured the identity of the database version specifically used for the CCA. This issue is raised because the results of chemical equilibrium problems are primarily dependent on the thermodynamic data used to represent pertinent reactions. As noted earlier, a complete copy of the data base is included in Novak 1997 and this updated version was included in the EPA mandated PAVT (Docket: A-93-02, II-G-26).

The other primary inputs to the FMT code are the chemical compositions of the Salado and Castile brines and the identity of solubility controlling phases expected to be present in the repository environment. Brine compositions are provided in Table SOTERM-1 of Appendix SOTERM. Specific solubility controlling phases are not clearly identified in Appendix SOTERM, but are provided in supplementary information in Docket: A-93-02, II-G-1, Ref. #479.

c.5) Any necessary licenses.

The code runs on OpenVMS AXP, versions 1.5 and 6.1 on DEC Alpha and Power Macintosh platforms. A FORTRAN 77 compiler is needed to recompile the codes, but no licenses are required for the FMT computer code.

c.6) An explanation of the manner in which models and computer codes incorporate the effects of parameter correlation.

The effects of parameter correlation are not explicitly discussed in the UM, RD/VVP, VD and ID. However, it is generally understood that equilibrium reactions result in nonlinear correlations between concentrations and master variables, such as pH or CO₂(g) fugacity, because of various hydrolysis and complexation reactions. These effects are explicitly accounted for in the reaction stoichiometries in the FMT thermodynamic database and related constants.

d) The Administrator or the Administrator's authorized representative may verify results of computer simulations used to support any compliance application by performing independent simulations. Data files, source codes, executable versions of computer software for each model, other material or information needed to permit the Administrator or the Administrator's authorized representative to perform independent simulations, and access to necessary hardware to perform such simulations, shall be provided within 30 calendar days of a request by the Administrator or the Administrator's authorized representative.

A study was undertaken by EPA to reproduce the concentrations of actinides presented in Table SOTERM-2 of the User's Manual and is discussed below.

The FMT model was used by the Department of Energy (DOE) to calculate concentrations of actinides based on solubility equilibria under expected repository conditions. The results form the basis for the actinide source term and are presented in Appendix SOTERM of the Compliance Certification Application. As part of the EPA review of the actinide source term a series of computer modeling runs was conducted with the FMT code to verify the results reported by DOE. During the course of conducting these modeling runs, incorrect results were obtained for Th(IV) and Np(V) under certain conditions. As a result, the FMT thermodynamic database was revised by Sandia National Laboratory (SNL) to correct values of ion interaction parameters to be more representative of experimental data. These revisions have resulted in calculated actinide concentrations that differ from those reported in the CCA PA as summarized below.

In an initial set of EPA computer modeling runs with the FMT model (version 2.0) conducted in January, 1997, results were obtained that, for the most part, approximated those reported by DOE in the CCA (Table A1-1). Differences of about 50% were found for Am(III) that could not be completely explained. They were presumably attributable to differences in the thermodynamic data for Am(III) species between the FMT database version used for verification compared to the

version used for the CCA. At the time of conducting these initial verification runs, there was some confusion at SNL about exactly which thermodynamic database had been used for the CCA calculations. These initial FMT verification runs relevant to the CCA were conducted for chemical conditions controlled by the equilibrium between brucite [$\text{Mg}(\text{OH})_2$] and magnesite [MgCO_3].

Later substantiated by experimental results (Docket: A-93-02, II-A-39), it was determined that chemical conditions in the repository would be more appropriately represented by the equilibrium between brucite and hydromagnesite [$\text{Mg}_5(\text{CO}_3)_4(\text{OH})_2 \cdot 4\text{H}_2\text{O}$] or, less likely, brucite and nesquehonite [$\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$]. Because these reactions result in different sets of pH and $\text{CO}_2(\text{g})$ partial pressure, factors that can strongly affect actinide solid solubilities, a series of FMT runs were conducted under conditions of brucite/hydromagnesite and brucite/nesquehonite equilibrium for comparison to the standard case of brucite/magnesite equilibrium used in the CCA.

These runs calculated Th(IV) and Np(V) concentrations so high that they were clearly in error (Table A1-2). The erroneously high concentrations were traced to unrepresentative values for ion interaction parameters for $\text{Th}(\text{CO}_3)_5^{-6}$ and Np(V)-carbonate species by Craig Novak of SNL, who also noticed the high concentrations at about the same time (Novak 1997). Novak subsequently modified the ion interaction parameters for Th(VI) and Np(V) species with chloride, sodium, and potassium based on values from recent experimental results (Docket: A-93-02, II-G-1, Ref. #249, Ref. #481 and Novak et al. 1996) to correct the FMT database. He documented the changes in the FMT database and produced calculations of actinide solubilities under conditions of equilibria between brucite/magnesite, brucite/hydromagnesite, and brucite/nesquehonite in Novak 1997. The calculated actinide concentrations are also summarized in Docket: A-93-02, II-A-39.

Because the version of the FMT database that was originally used for the CCA was in error, calculated actinide solubilities based on it were no longer considered valid for verification purposes. Instead, solubility calculations described in Novak 1997 were obtained with the corrected database and were considered to be the most appropriate targets for verification. Additionally, version 2.2 of the FMT code was used in these calculations because of its availability at the time and improved output of parameters such as $\text{CO}_2(\text{g})$ partial pressure (Novak 1997).

The results of the FMT verification runs closely match those provided by Novak

(1997) for conditions of equilibrium with different brucite/magnesium carbonate solids (Tables A1-3 and A1-4). Results are provided for two different hydromagnesite stoichiometries because it was not clear which would be prevalent under the repository conditions, although the calculated actinide concentrations for both forms are not widely different.

Experimental studies conducted at SNL have shown that nesquehonite forms initially upon reaction between brucite, air, and brine (Docket: A-93-02, II-A-39). The nesquehonite rapidly converts to hydromagnesite in a matter of days to weeks. Although SNL scientists, argue that the hydromagnesite should eventually convert to magnesite based on analogies with some natural experimental systems at elevated temperatures (*ibid.*), this reaction has not been observed to proceed completely under the low temperature conditions of their experiments. Consequently, to be consistent with the thermodynamic approach used to conceptualize the repository chemical conditions and actinide source term, the equilibria between brucite and hydromagnesite must be considered as the most probable reaction controlling the pH and CO₂(g) partial pressure in the presence of the brines and MgO backfill.

A comparison of the actinide concentrations calculated under these conditions (Tables 3 and 4) shows that they are generally lower than those originally calculated for brucite/magnesite equilibria presented in the CCA (see Table A1-1). The lower concentrations are a direct result of the modifications to the FMT database made to correct the errors observed in modeling runs described above and in Novak 1997. However, these lower concentrations should be more accurate because of the improvements to the FMT thermodynamic database made since the submittal of the CCA.

Table A1-1. Comparison of FMT results provided by Docket: A-93-02, II-G-1, Ref. #480 for the CCA to those obtained in the verification runs for the SPC brine (Salado) and ERDA6 brine (Castile). (Concentration - molal)

Element	Salado Brine		Castile Brine	
	Novak ^d	Verif.	Novak ^d	Verif.
Hydrogen	1.11E+02	1.11E+02	1.11E+02	1.11E+02
Oxygen	5.59E+01	5.59E+01	5.65E+01	5.65E+01
Sodium	4.69E+00	4.69E+00	6.20E+00	6.20E+00

	Salado Brine		Castile Brine	
Element	Novak ^d	Verif.	Novak ^d	Verif.
Potassium	1.05E+00	1.05E+00	1.09E-01	1.07E-01
Magnesium	5.09E-01	5.09E-01	4.43E-02	4.33E-02
Calcium	3.31E-02	3.31E-02	1.33E-02	1.35E-02
Chlorine	6.67E+00	6.67E+00	5.97E+00	5.97E+00
Sulfur	6.02E-02	6.02E-02	1.91E-01	1.87E-01
Carbon	4.08E-05	4.10E-05	3.15E-05	3.18E-05
Boron	2.72E-02	2.73E-02	7.08E-02	6.92E-02
Bromine	1.36E-02	1.36E-02	1.24E-02	1.21E-02
Th(IV)	4.98E-09	5.01E-06	6.78E-09	6.91E-09
Am(III)	4.39E-07	6.67E-07	4.12E-07	7.37E-08
Np(V)	2.64E-06	2.63E-06	2.53E-06	2.56E-06
pH	8.69	8.69	9.24	9.24
pmH	9.37	9.37	9.89	9.90
Charge	-8.17E-16	1.25E-17	-1.97E-15	2.07E-15
Equilibria	halite anhydrite AmOHCO ₃ (s) ThO ₂ (am) KNpO ₂ CO ₃ ·2H ₂ O(s) brucite magnesite		halite anhydrite AmOHCO ₃ (s) ThO ₂ (am) KNpO ₂ CO ₃ ·2H ₂ O(s) brucite magnesite	

Table A1-2. Brine compositions and actinide concentrations calculated with the CCA version of FMT for different magnesium carbonate equilibria for the SPC brine (Salado) and ERDA6 brine (Castile) showing high Th(IV) and Np(V) concentrations. (Concentration - molal)

	Salado Brine		Castile Brine	
	Brucite/ Hvdromaonesite	Brucite/ Nesauehonite	Brucite/ Hvdromaonesite	Brucite/ Nesauehonite

	Salado Brine		Castile Brine	
Element	Brucite/ Hydromagnesite [Mg ₅ (CO ₃) ₄ (OH) ₂ ·4H ₂ O]	Brucite/ Nesquehonite [MgCO ₃ ·3H ₂ O]	Brucite/ Hydromagnesite [Mg ₅ (CO ₃) ₄ (OH) ₂ ·4H ₂ O]	Brucite/ Nesquehonite [MgCO ₃ ·3H ₂ O]
Hydrogen	1.11E+02	1.11E+02	1.11E+02	1.11E+02
Oxygen	5.78E+01	5.98E+01	5.67E+01	5.90E+01
Sodium	3.81E+00	2.01E+00	5.64E+00	4.15E+00
Potassium	9.67E-01	8.78E-01	1.06E-01	9.67E-02
Magnesium	1.35E+00	2.66E+00	3.64E-01	1.57E+00
Calcium	4.02E-02	1.41E-02	1.07E-02	3.53E-02
Chlorine	6.60E+00	6.29E+00	5.97E+00	6.00E+00
Sulfur	1.22E-01	4.10E-01	2.23E-01	2.29E-01
Carbon	5.59E-01	8.01E-01	5.39E-03	7.64E-01
Boron	2.52E-02	2.25E-02	6.88E-02	6.28E-02
Bromine	1.25E-02	1.12E-02	1.20E-02	1.10E-02
Th(IV)	1.12E-01	9.98E-02	1.02E-03	1.53E-01
Am(III)	1.64E-07	2.19E-08	4.94E-08	5.61E-08
Np(V)	1.08E-06	9.99E-02	1.87E-06	1.93E-05
pH	8.52	8.40	8.79	8.56
pmH	9.18	9.02	9.42	9.15
log [CO ₂] (bar)	-5.63	-4.68	-5.65	-5.51
Charge	7.92E-15	5.74E-15	2.06E-15	4.63E-15
Equilibria	halite anhydrite AmOHCO ₃ (s) ThO ₂ (am) KNpO ₂ CO ₃ ·2H ₂ O(s) brucite magnesite calcite Mg-oxvchloride	halite anhydrite AmOHCO ₃ (s) ThO ₂ (am) KNpO ₂ CO ₃ ·2H ₂ O(s) brucite magnesite calcite	halite anhydrite AmOHCO ₃ (s) ThO ₂ (am) KNpO ₂ CO ₃ ·2H ₂ O(s) brucite magnesite calcite glauberite	halite anhydrite AmOHCO ₃ (s) ThO ₂ (am) KNpO ₂ CO ₃ ·2H ₂ O(s) brucite magnesite calcite glauberite

Table A1-3. Brine compositions and actinide concentrations calculated with version 2.2 of FMT with corrected database for different magnesium carbonate equilibria for the SPC brine (Salado formation). (Concentration - molal)

Element	Brucite/ Hydromagnesite [Mg ₅ (CO ₃) ₄ (OH) ₂ ·4H ₂ O]		Brucite/ Hydromagnesite [Mg ₄ (CO ₃) ₃ (OH) ₂ ·3H ₂ O]		Brucite/ Nesquehonite [MgCO ₃ ·3H ₂ O]		Brucite/ Magnesite [MgCO ₃]	
	Novak	Verif.	Novak	Verif.	Novak	Verif.	Novak	
Hydrogen	1.11E+02	1.11E+02	1.11E+02	1.11E+02	1.11E+02	1.11E+02	not reported	1.
Oxygen	5.59E+01	5.59E+01	5.59E+01	5.59E+01	5.59E+01	5.59E+01	not reported	5.
Sodium	4.68E+00	4.69E+00	4.68E+00	4.69E+00	4.66E+00	4.69E+00	not reported	4.
Potassium	1.07E+00	1.05E+00	1.07E+00	1.05E+00	1.11E+00	1.05E+00	not reported	1.
Magnesium	5.09E-01	5.09E-01	5.09E-01	5.09E-01	5.30E-01	5.30E-01	not reported	5.
Calcium	3.29E-02	3.31E-02	3.29E-02	3.31E-02	3.34E-02	3.39E-02	not reported	3.
Chlorine	6.68E+00	6.67E+00	6.68E+00	6.67E+00	6.69E+00	6.66E+00	not reported	6.
Sulfur	6.06E-02	6.02E-03	6.06E-02	6.02E-02	6.22E-02	6.10E-02	not reported	6.
Carbon	4.13E-04	4.13E-04	5.38E-04	5.38E-04	2.26E-02	2.27E-02	not reported	1.
Boron	2.77E-02	2.73E-02	2.77E-02	2.73E-02	2.88E-02	2.72E-02	not reported	2.
Bromine	1.39E-02	1.36E-02	1.39E-02	1.36E-02	1.44E-02	1.36E-02	not reported	1.
Th(IV)	1.37E-08	1.37E-08	1.75E-08	1.75E-08	7.22E-04	7.49E-04	not reported	1.
Am(III)	1.08E-07	1.06E-07	8.31E-08	8.21E-08	3.64E-07	3.53E-07	not reported	7.
Np(V)	1.38E-07	1.40E-07	1.23E-07	1.25E-07	1.36E-07	1.45E-07	not reported	1.
pH	8.69	8.69	8.69	8.69	8.69	8.69	not reported	
pmH	9.37	9.37	9.37	9.37	9.37	9.36	not reported	
log CO ₂ (g)	-5.50	-5.50	-5.39	-5.39	-3.84	-3.84	not reported	
Charge	5.87E-15	5.82E-15	8.97E-15	3.07E-15	1.30E-14	3.72E-15	not reported	4.

	Brucite/ Hydromagnesite [Mg ₅ (CO ₃) ₄ (OH) ₂ ·4H ₂ O]		Brucite/ Hydromagnesite [Mg ₄ (CO ₃) ₃ (OH) ₂ ·3H ₂ O]		Brucite/ Nesquehonite [MgCO ₃ ·3H ₂ O]		Brucite/ Magnesite [MgCO ₃]	
Element	Novak	Verif.	Novak	Verif.	Novak	Verif.	Novak	
Equilibria	Anhydrite MgOxychloride Brucite Hydromagnesite Halite ThO ₂ (am) AmOHCO ₃ KNpO ₂ CO ₃		Anhydrite MgOxychloride Brucite Hydromagnesite Halite ThO ₂ (am) AmOHCO ₃ KNpO ₂ CO ₃		Anhydrite MgOxychloride Brucite Nesquehonite Halite ThO ₂ (am) AmOHCO ₃ KNpO ₂ CO ₃		Anhydrite Brucite Magnesite Halite ThO ₂ (am) Am(OH) ₃ (s) KNpO ₂ CO ₃	

Table A1-4. Brine compositions and actinide concentrations calculated with version 2.2 of FMT with corrected database for different magnesium carbonate equilibria for the ERDA6 brine (Castile formation). (Concentration - molal)

	Brucite/ Hydromagnesite [Mg ₅ (CO ₃) ₄ (OH) ₂ ·4H ₂ O]		Brucite/ Hydromagnesite [Mg ₄ (CO ₃) ₃ (OH) ₂ ·3H ₂ O]		Brucite/ Nesquehonite [MgCO ₃ ·3H ₂ O]		Brucite/ Magnesite [MgCO ₃]	
Element	Novak	Verif.	Novak	Verif.	Novak	Verif.	Novak	
Hydrogen	1.11E+02	1.11E+02	1.11E+02	1.11E+02	1.11E+02	1.11E+02	not reported	1.
Oxygen	5.66E+01	5.65E+01	5.66E+01	5.65E+01	5.67E+01	5.66E+01	not reported	5.
Sodium	6.20E+00	6.20E+00	6.20E+00	6.20E+00	6.18E+00	6.18E+00	not reported	6.
Potassium	1.11E-01	1.07E-01	1.11E-01	1.07E-01	1.16E-01	1.06E-01	not reported	1
Magnesium	4.57E-02	4.40E-02	4.59E-02	4.42E-02	7.74E-02	7.35E-02	not reported	4
Calcium	1.34E-02	1.36E-02	1.34E-02	1.36E-02	1.61E-02	1.64E-02	not reported	1
Chlorine	5.97E+00	5.97E+00	5.97E+00	5.97E+00	5.96E+00	5.96E+00	not reported	5.
Sulfur	1.91E-01	1.87E-01	1.91E-01	1.87E-01	1.93E-01	1.90E-01	not reported	1
Carbon	7.77E-04	7.91E-04	1.01E-03	1.03E-03	3.54E-02	3.67E-02	not reported	3
Boron	7.21E-02	6.92E-02	7.21E-02	6.92E-02	7.48E-02	6.91E-02	not reported	7
Bromine	1.26E-02	1.21E-02	1.26E-02	1.21E-02	1.31E-02	1.21E-02	not reported	1
Th(IV)	4.63E-08	4.70E-08	5.98E-08	6.07E-08	1.19E-03	1.30E-03	not reported	3

	Brucite/ Hydromagnesite [Mg ₅ (CO ₃) ₄ (OH) ₂ ·4H ₂ O]		Brucite/ Hydromagnesite [Mg ₄ (CO ₃) ₃ (OH) ₂ ·3H ₂ O]		Brucite/ Nesquehonite [MgCO ₃ ·3H ₂ O]		Brucite/ Magnesite [MgCO ₃]	
Element	Novak	Verif.	Novak	Verif.	Novak	Verif.	Novak	
pH	9.24	9.24	9.23	9.24	9.17	9.18	not reported	
pmH	9.89	9.90	9.89	9.89	9.82	9.83	not reported	
log CO ₂ (g)	-5.50	-5.50	-5.39	-5.39	-3.87	-3.87	not reported	
Charge	1.54E-14	1.55E-15	7.56E-15	4.09E-16	1.62E-15	1.95E-15	not reported	5
Equilibria	Anhydrite Brucite Hydromagnesite Halite Glauberite ThO ₂ (am) KNpO ₂ CO ₃ AmOHCO ₃		Anhydrite Brucite Hydromagnesite Halite Glauberite ThO ₂ (am) KNpO ₂ CO ₃ AmOHCO ₃		Anhydrite Brucite Nesquehonite Halite Glauberite ThO ₂ (am) Na ₃ NpO ₂ (CO ₃) ₂ NaAm(CO ₃) ₂ ·6H ₂ O		Anhydrite Brucite Magnesite Halite Glauberite ThO ₂ (am) Am(OH) ₃ (s) KNpO ₂ CO ₃	

REFERENCES

- Bynum, R. V. 1996. *Analysis to Estimate the Uncertainty for Predicted Actinide Solubilities*. WBS 1.1.10.1.1, Rev. 0, effective date 9/3/96 (WPO41374).
- Novak, C. F. 1997. *Calculation of Actinide Solubilities in WIPP SPC and ERDA6 Brines under MgO Backfill Scenarios Containing Either Nesquehonite or Hydromagnesite as the Mg-CO₃ Solubility-Limiting Phase*. Memo to R. Vann Bynum, dated April 21, 1997, Sandia National Laboratory, Albuquerque, New Mexico.
- Novak, C. F., I. Al Mahamid, K. A. Becraft, S. A. Carpenter, N. Hakem, and T. Prussin 1996b. *Measurement and Thermodynamic Modeling of Np(V) Solubility in Dilute through Concentrated K₂CO₃ Media*. SAND96-1604J, Sandia National Laboratory, Albuquerque, New Mexico.
- Novak, C. F., N. J. Dhooge, H. W. Papenguth, and R. F. Weiner 1995. *Systems Prioritization Method - Iteration 2 Baseline Position Paper: Actinide Source Term*. Sandia National Laboratory, Albuquerque, New Mexico, dated March 31, 1995.

APPENDIX A2

PANEL COMPUTER CODE EVALUATION

This evaluation examines PANEL Version 3.60. PANEL's role in the CCA performance assessment (PA) is to estimate the mobilized radioactive contaminant load in the brine phase of the brine/gas mixture that seeps or flows through the repository's decommissioned waste panels. This code is used in S6 scenarios in which 2 boreholes penetrate the same waste panel—with the second borehole also penetrating a pressurized Castile brine pocket. When applicable—i.e., if a borehole intrudes into a pressurized repository—PANEL is able to calculate the contaminant load contained in the volume of brine that would be released directly to the surface.

EPA REVIEW

a) Any compliance application shall include:

a.1) A description of the conceptual models and scenario construction used to support any compliance application.

Descriptions of the model and related methods are provided in the WIPP CCA (Docket: A-93-02, II-G-1, Volume XI, Appendix PANEL), the PANEL User's Manual (UM) (Docket: A-93-02, II-G-3, Volume II), and the Task 2 Analysis Package (Docket: A-93-02, II-G-09).

a.2) A description of plausible alternative conceptual model(s) seriously considered but not used to support such application, and an explanation of the reason(s) why such model(s) was not deemed to accurately portray performance of the disposal system.

As employed in the CCA, PANEL performs two basic functions: the code calculates radioactive decay and calculates the amount of radioactive material dissolved in brine and transported from a waste panel—given a volume of brine within the waste panel, the solubilities of the radionuclides present, and the brine outflow. For the first of these functions, radioactive decay, there is no question of alternative models, since radioactive decay is governed by well documented physical process. The parameters, including brine volume, radionuclide solubilities, and brine outflow that govern the second function, are calculated in other codes and then entered into PANEL. The chief assumptions made within PANEL are: a) all of a given radionuclide contained within a waste panel is

instantaneously available for mixing with the brine present at a given time-step, and b) the maximum possible amount of a radionuclide instantly goes into solution. Also note for calculation purposes, PANEL lumps together the effects of dissolution and colloidal suspension. No other approach is discussed, but the implementation of the code maximizes the amount of material mobilized and is conservative.

a.3) Documentation that:

a.3.i) conceptual models and scenarios reasonably represent possible future states of the disposal system.

PANEL supports a framework based on conceptual models and scenarios that are described in Volume I of the CCA (Docket: A-93-02, II-G-1, Chapter 6), in the PANEL UM (Docket: A-93-02, II-G-3, Volume II), and in the Task 2 Analysis Package (Docket: A-93-02, II-G-09). The models and scenarios appear to reasonably represent possible future states of the disposal system.

a.3.ii) mathematical models incorporate equations and boundary conditions which reasonably represent the mathematical formulation of the conceptual models.

The equations in PANEL are described by the UM (*ibid.*) and they reasonably represent the conceptual models used.

a.3.iii) numerical models provide numerical schemes which enable the mathematical models to obtain stable solutions.

The mathematics used in PANEL produce straightforward analytical solutions to the relevant equations. No numerical methods are used.

a.3.iv) computer models accurately implement the numerical models; i.e., computer codes are free of coding errors and produce stable solutions.

The performance of the PANEL code is described in the UM (*ibid.*) and documented in the PANEL Validation Document (VD) (Docket: A-93-02, II-G-3, Volume II). The computer code used in PANEL appears to accurately implement the numerical models.

a.3.v) conceptual models have undergone peer review according to § 194.27.

The peer review of the conceptual models that PANEL supports is described in the Volume I of the CCA and Appendix PEER, PEER 1 (Docket: A-93-02, II-G-1).

b) Computer codes used to support any compliance application shall be documented in a manner that complies with the requirements of ASME NQA-2a-1990 addenda, part 2.7, to ASME NQA-2-1989 edition.
(Incorporation by reference as specified in § 194.5)

The four QA documents reviewed for PANEL Version 3.60 are (Docket: A-93-02, II-G-3, Volume II):

User's Manual (UM) (2)

Implementation Document (ID) (5)

Requirements Document/ Validation & Verification Plan (RD/VVP) (6)

Validation Document (VD) (9)

These documents are discussed in order below.

User's Manual

PANEL performs two basic functions by calculating: the radioactive decay of the significant radionuclides contained in the WIPP inventory and the amount of each nuclide mobilized in brine including that removed by transport from a waste panel. In relation to these calculations, the UM adequately explains the technical basis for the code, provides a description of the equations used for the processes modeled by the code, and explains how the equations were selected or developed.

The UM provides sufficient information to run the code, assuming the user is familiar with VMS and Digital Command Language. The UM provides a chart of the run sequence for PANEL to illustrate the codes that must be run prior to PANEL to provide the necessary input. Examples of input and output files are provided in the UM.

During the Sandia QA review of PANEL, it was noted that the PANEL test case for radioactive decay only tested one radionuclide and not the entire list used in CCA runs. The conclusion made at the time of the test is that the single radionuclide case is adequate to evaluate the code's algorithm and further testing was not considered necessary. This is based on the provision that radioactive half-lives and decay chains are hard-wired into PANEL for the remaining radionuclides and that this can be verified by the documentation in the UM. The Task 2 Analysis Package, dated December 19, 1996 (Docket: A-93-02, II-G-9, pp. 56-57), compares the PANEL data to the PA Data Base values obtained from the independent ORIGEN computer code (4) and finds no significant differences. Based on this, the PANEL data are acceptable—also see the additional remarks

provided in the Requirements Document/Validation & Verification Plan (RD/VVP) discussion below.

Implementation Document

The ID provides a complete listing of the source code.

Requirements Document/Validation & Verification Plan

Three functional requirements are listed in the RD/VVP. The RD/VVP notes that PANEL must be able to compute the following at all future times up to 10,000 years:

R.1 The mass of each radioisotope present in the repository by accounting for radioactive decay.

R.2 The amount of each radioisotope that transforms into a mobile phase.

R.3 The amount of each mobilized radioisotope that is transported by the brine flow and removed from the waste area.

These functions appropriately represent the usage of PANEL in the CCA PA. The VVP presents an approach to test these functions. The radioactive decay function is tested separately from the other two functions. This is appropriate since decay and mobilization occur independent of each other. The independent testing also simplifies the verification of results. Requirement R.1, the calculation of radioactive decay, is tested by setting up an input file specifying a given quantity of a single radioisotope, assuming no mobilization nor transport occurs, and then evaluating the results. The transport test uses input for two radioisotopes with extremely long half-lives—so radioactive decay is negligible—and assumes a given intrusion time and brine inflow. The correct performance of the calculations in this test verifies requirements R.2 and R.3.

The acceptance criteria specified in the PANEL Version 3.60 RD/VVP rely on comparing the present results with those from the preceding version, PANEL Version 3.50ZO. This was accomplished through a comparison with independent test results for the preceding version. This is acceptable if the documentation for PANEL Version 3.50ZO is available for review and is determined to be adequate for this evaluation (see discussion under Validation Document below).

The RD/VVP notes that while the test case for radioactive decay serves to validate PANEL's decay model, it does not provide verification of all the decay chains

available in PANEL. The RD/VVP states that the exercise of documenting and verifying PANEL's decay chains and isotope half-lives "will be performed as part of the *WIPP PA User's Manual for PANEL Version 3.60*" (2). As noted in the preceding discussion of the UM, this material is not present in the manual, but the issue is addressed in the Task 2 Analysis Package. While this documentation should be corrected, the lack of decay chain information does not materially affect the validity of the PANEL code.

Validation Document (VD)

The VD presents the results of running the test cases for radioactive decay and for transport, and compares the results to the acceptance criteria specified in the RD/VVP. The results of the test cases fulfill the requirements of the acceptance criteria from the PANEL Version 3.60 RD/VVP. Noting the caveat concerning availability and acceptability as stated above, the UM (1), RD/VVP (2), and VD (3) for PANEL Version 3.50ZO were also reviewed. These documents demonstrate that PANEL Version 3.50ZO was tested and gave results that met acceptance criteria based on comparison to independent calculations. EPA also successfully ran the test cases for PANEL Version 3.60 which are adequate for demonstrating PANEL's performance.

c) Documentation of all models and computer codes are included as part of any compliance application performance assessment calculation shall be provided. Such documentation shall include, but not be limited to:

c.1) Description of the theoretical backgrounds of each model and the method of analysis or assessment.

Description of the theoretical backgrounds and methods of analysis used in PANEL are provided in Volume I of the CCA, the UM, and in the Task 2 Analysis Package.

c.2) General descriptions of the models; discussions of the limits of applicability of each model; detailed instructions for executing the computer codes, including hardware and software requirements, input and output formats with explanations of each input and output variable and parameter (e.g., parameter name and units); listings of input and output files from a sample computer run; and reports on code verification, benchmarking, validation, and quality assurance procedures.

General descriptions of the models used in PANEL are provided in Volume I of the

CCA (pp. 6-174 - 6-179), the UM (pp. 8-17), and in the Task 2 Analysis Package (pp. 18-23). The UM provides detailed instructions for executing the code, along with sample input and output files. The VD provides verification and validation information.

c.3) Detailed descriptions of the structure of computer codes and complete listings of the source codes.

The structure of the PANEL code is described in the UM. A listing of the source code is contained in the Implementation Document (ID).

c.4) Detailed descriptions of data collection procedures, sources of data, data reduction and analysis, and code input parameter development.

Input parameters are discussed in the UM. Brine volume and brine outflow are calculated by another code such as BRAGFLO or BRAGFLO_DBR and are then placed in an input file for PANEL. One of the most critical inputs to PANEL are the solubilities which are calculated by the ALGEBRA code. A detailed description of the development of the solubilities used in PANEL is contained in the Task 2 Analysis Package.

c.5) Any necessary licenses.

No licenses are necessary for PANEL.

c.6) An explanation of the manner in which models and computer codes incorporate the effects of parameter correlation.

Three of the principal parameters used in PANEL (radionuclide half-lives, radionuclide inventory, and solubilities) are not interrelated. Two principal parameters (brine volume and brine outflow) are the result of calculations performed by a predecessor code (e.g., BRAGFLO or BRAGFLO_DBR) and are not correlated as used in PANEL.

d) The Administrator or the Administrator's authorized representative may verify results of computer simulations used to support any compliance application by performing independent simulations. Data files, source codes, executable versions of computer software for each model, other material or information needed to permit the Administrator or the Administrator's authorized representative to perform independent simulations, and access to necessary hardware to perform such simulations, shall be provided within 30 calendar days of a request by the

Administrator or the Administrator's authorized representative.

EPA was given access to the Sandia computer system and to files described as necessary to run PANEL. Information on operation of the Sandia computer system and specific information on running PANEL was provided. However, during the initial attempts to verify the results of the two VD tests for PANEL, the Agency discovered that corrupted versions of the necessary input files were contained in CCA-CMS. Sandia personnel subsequently found that uncorrupted versions of the files exist on back-up tapes dated prior to June 12, 1996. The EPA then accessed the uncorrupted files on February 24, 1997, and successfully ran the PANEL test cases.

REFERENCES

Oak Ridge National Laboratory, RSIC Computer Code Collection, "ORIGEN 2.1; Isotope Generation and Depletion Code, Matrix Exponential Method," December 1991 included in the CCA.

WIPP PA User's Manual for PANEL, Version 3.50ZO, WPO #37361, September 29, 1995.

WIPP PA Requirements Document & Validation and Verification Plan for PANEL, Version 3.50ZO, WPO# 24326, September 28, 1995.

WIPP PA Validation Document for PANEL, Version 3.50ZO, WPO# 24328, September 28, 1995.

See Appendix B(3) for a listing of docketed references.

APPENDIX A3 SANTOS COMPUTER CODE EVALUATION

The computer code SANTOS enters the Compliance Certification Application (CCA) via "Creep Closure" as described in 6.4.3.1 Creep Closure, pages 6-97 to 6-99 (Docket: A-93-02, II-G-1, Volume I, Chapter 6). Supplementary information is contained in Appendix PORSURF and attachments to Appendix PORSURF which contain additional references (Docket: A-93-02, II-G-1, Volume XVI). SANTOS provides for two-dimensional stress analysis of repository rooms experiencing finite creep strains.

Creep closure histories from SANTOS calculations provide room pressure - room porosity histories for input to the fluid-flow computer code BRAGFLO. The

actual mechanics of room closure are not considered important except as interbed fracture may occur.

EPA REVIEW

a) *Any compliance application shall include:*

a.1) **A description of conceptual models and scenario construction used to support any compliance application.**

The conceptual model for creep closure is described in the CCA, Section 6.4.3.1 Creep Closure, pages 6-97 to 6-99, and in the supporting references in Appendices PORSURF.1 and PORSURF Attachment 1.

The model focuses on salt creep that results in time-dependent reduction of disposal room volume. Creep is attributed to differences in principal stresses in the salt induced by room excavation. The pre-excavation stress state is hydrostatic, characterized by equality of principal stresses. After excavation, the salt flows like a viscous fluid until the stress state becomes hydrostatic once again. Volumetric strain of the salt is considered elastic similar to fluids that lack volumetric viscosity.

Total room volume is composed of two parts: a solid part equal to the volume of solid waste placed in a room and a void part equal to the room volume less the solid volume. Fluid pressure in the room void space and resistance of solid waste to compression impede room volume reduction. Room solid volume is considered constant, although decomposition of the solid waste by chemical and biological processes occurs in time. These processes generate gas pressure in addition to the pressure increase caused by compression of air trapped within a sealed room. Pressure generation caused by waste decomposition is governed by the ideal gas law and waste decomposition rate which varies in time.

Room pressure may be generated in excess of the weight of the overlying strata and cause room volume reduction to cease and, indeed, to begin a relative expansion. This eventuality is cause for concern since it creates the possibility that fracture of less ductile anhydrite beds near repository rooms will occur enhancing potential fast-flow paths to and from waste rooms.

The importance of salt creep and related room void volume and gas pressure variation is in connection with fluid flow. Void volume relates to gas and brine storage, while gas pressure directly influences fluid flow rate. Both are input conditions to fluid flow calculations. The details of the closure process are

therefore not considered important, only the consequences in terms of fluid pressure and room void volume. In this regard, room closure rate is slow enough to not affect the active life of the repository (about 25 years), but is much faster than waste decomposition. Closure is essentially complete within about one hundred years, while gas pressure build-up is maintained over hundreds of years.

a.2) A description of plausible alternative conceptual model(s) seriously considered but not used to support such application, and an explanation of the reason(s) why such model(s) was not deemed to accurately portray performance of the disposal system.

There appear to be no alternative models to the *porosity surface* approach with the exception of a reference by Freeze 1996 (Docket: A-93-02, II-G-1, Ref. #258) to a coupled model of fluid flow and porous solid deformation that is dismissed as impractical. In this regard, care needs to be exercised in the understanding of the label *coupled model*. The usual understanding of coupled models in mechanics implies simultaneous occurrence of several distinct phenomena, for example, fluid flow in porous media and deformation of the solid skeleton. However, coupling in the CCA refers to linkage between computer codes, for example, between SANTOS and BRAGFLO. Alternative conceptual models noted by Freeze and coauthors thus refer to the linkage, that is, *coupling* between computer codes and not to conventional coupled models in continuum mechanics. Similarly, alternatives to the conceptual model associated with salt creep are alternatives to the porosity surface linkage scheme as discussed by Freeze, et al. (Docket: A-93-02, II-G-1, Ref. #260 and Ref. #261).

An interesting calculation in Freeze, et al. (*ibid.*, Ref. #260) is described in an appendix (memorandum to B.M. Butcher from C.M. Stone). The calculation is in the spirit of a genuinely coupled continuum model in which fluid flow and solid deformation calculations are interleaved. One model solution is obtained for a given time step and then the other is obtained using the results from the first part and so on. This *coupled structural/porous flow* calculation leads to fluid pressures in the Salado of 20 MPa at substantial distances from repository rooms. In view of overburden stresses of 14.5 MPa, such a fluid pressure—through the concept of effective stress as explained in Chapter 6 of the CCA (equation 1, page 6-98, $\sigma_T = \sigma_e + p$ where σ_T is the weight of the overburden, p is the pressure of the pore fluid and σ_e is the stress supported by the porous matrix)—gives rise to a tensile stress in the Salado of 5.5 MPa (800 psi) which is likely to be well above salt tensile strength. The equation applies to each of the three principal stresses at a point. As

a consequence, the overburden will be lifted as the salt disintegrates under hydrostatic tension. The damage would be expected to greatly enhance permeability. However, the purpose of the calculation is to assess the role of solid deformation on brine flow to repository rooms—i.e., to see whether the salt *squeeze* would increase the volume of room flow from the Salado. The consequences of salt failure in tension were not explored.

a.3) Documentation that:

a.3.i) conceptual models and scenarios reasonably represent possible future states of the disposal system.

Scenarios in terms of features, events, and processes (FEP's) are described in the CCA, Chapter 6, Section 6.2, page 6-35 (Docket: A-93-02, II-G-1, Volume I).

Discussion of the adequacy of the porosity surface approach is referenced to a document by Freeze (Docket: A-93-02, II-G-1, Ref. #258). Coupling between room closure and fluid flow is stated to be through room pressure and that this type of coupling is valid for PA computations. The work by Freeze, et al. (Docket: A-93-02, II-G-1, Ref. #260 and Ref. #261) is cited as supporting evidence. The main concern in this work is whether the constant volume room model used in the fluid flow codes is consistent with the variable volume room model used in the solid *creep* codes. The conclusion is that a consistent linkage is possible provided the room pressure histories are similar and room void volume is properly taken into account in the flow codes.

Repository subsidence in any form is considered to be of no consequence as are roof falls, pillar spalls and even floor separation and fracture. Such events are considered normal features of salt mine operation and will be handled accordingly.

The relatively new M-D model developed by Sandia National Laboratories from micromechanics mechanisms—with the goal of improved predictability of creep closure—turns out to be most dependent on an "unidentified" mechanism. A 12.5 adjustment factor for implementation is required by the earlier R-D model to account for transitory creep leading to the steady-state. The M-D model multiplies the steady-state creep rate by a function, instead of a constant, to account for transient creep in arriving at the actual creep rate of the halite.

a.3.ii) mathematical models incorporate equations and boundary conditions which reasonably represent the mathematical formulation of the conceptual models,

A description of spatial boundary conditions is found in PORSURF Attachment 1,

page 1 (Docket: A-93-02, II-G-1, Volume XVI). In this description, a typical two-dimensional strip of a half-room and half-pillar is considered in a tunnel-like vertical cross-section. Displacements normal to the sides of the strip are prevented. Forces representing the overburden load are applied to the strip top and bottom. The exposed surfaces of the room and waste package must support applied tractions corresponding to room gas pressure. A typical repository room is about 10 m wide, 4 m high, and 91 m long. Rooms are spaced on about 40 m centers. A two-dimensional cross-section ("strip") is therefore a reasonable representation of a typical repository room and pillar, and the boundary conditions used are proper for analyses done.

Where repository rooms are connected to access tunnels and shafts, the geometry is three-dimensional. Analysis of the closure mechanics would require a three-dimensional creep code. However, such regions of the WIPP are not used for waste containment and are important only to operation of the mine. Of course, these regions will also creep to closure in time. However, the functional life of room seals may be an open question, so connection between rooms and access tunnels is probable, given the long life of the repository. The effect of connection would be to increase void volume and therefore to reduce gas pressure. Both appear to be beneficial to waste containment. The enormous cost of a lengthy series of three-dimensional analyses of such scenarios appears to be unjustified by any potential quantitative insight to be gained.

a.3.iii) numerical models provide numerical schemes which enable the mathematical models to obtain stable solutions,

The SANTOS Verification and Qualification Document, (Docket: A-93-02, II-G-3, Volume II, pages 1-1 to 21-11) contains a number of test problems that demonstrate solutions obtained. These test systematically exercise various aspects of SANTOS including the large displacement, large strain capability needed for creep closure analysis. Problem 20 is of particular interest because of the benchmark comparisons of SANTOS with the SANCHO, SPECTRUM and ANSALT codes. The comparison problem (Problem 20) is the isothermal strip model of a half-room and half-pillar geometry that contains various strata (salt, anhydrite and clay seams) represented by slide lines. SANTOS meets the benchmark criteria. This same problem (Problem 20) was rerun by EPA during a recent technical qualification study at Sandia National Laboratories with identical results.

a.3.iv) computer models accurately implement the numerical models, i.e.,

computer codes are free of coding errors and produce stable solutions,

The SANTOS Verification and Qualification Document (*ibid.*) contains a number of tests problems demonstrating that the computer model implements the numerical model. Theoretically, there can be no guarantee that a computer code is free of coding errors or conflicts. However, numerous example problems and a long history of successful code application indicate that SANTOS is reliable. This inference means that the code functions as intended. Given physically realistic input data, the output data from a well-converged program run can be viewed with confidence. In this regard, Problem 20 solved by SANTOS shows similar results to the same problem solved by other computer codes, specifically, SANCHO, SPECTRUM and ANSALT.

a.3.v) conceptual models have undergone peer review according to §194.27,

The conceptual model of creep closure has undergone peer review as summarized in Appendix PEER, PEER 1 (Docket: A-93-02, II-G-1, Volume XII). The report concludes that the models (conceptual, mathematical, numerical) are adequate and implemented accurately with respect to the porosity surface approach. The report also concludes that long-term validity could not be assessed in the absence of long-term observations. Long-term refers to thousands of years. Observations extend over a period of about ten years. There were no dissenting opinions amongst the peer review panelists.

b) Computer codes used to support any compliance application shall be documented in a manner that complies with the requirements of ASME NQA-2a-1990 addenda, part 2.7, to ASME NQA-2-1989 edition.

See CARD 22 for additional discussion (Docket: A-93-02, III-B-2).

Technical evaluation of SANTOS quality assurance is based on WPO #35673 - Quality Assurance Document for SANTOS (Version 2.0.0) and WPO #35675 - SANTOS - Verification and Qualification Document (Docket: A-93-02, II-G-3, Volume II).

c) Documentation of all models and computer codes are included as part of any compliance application performance assessment calculation shall be provided.

The documents Quality Assurance Document for SANTOS (Version 2.0.0), SANTOS User's Manual and SANTOS - Verification and Qualification Document address this requirement in detail (*ibid.*). Comments on some of these key

documents are provided below.

1) Design document (for new computer codes)

SANTOS is not a new computer code nor was it specifically developed for WIPP application, so no design document is required. In this regard, earlier analyses for the WIPP Project were done using SANCHO. SANTOS replaced SANCHO after careful benchmark analyses and comparisons. These results are described by Stone in a memorandum report that is contained in the document by Freeze, et al., 1995 (Docket: A-93-02, II-G-1, Ref. #260). Results for gas generation rates of $f=0.0$ and $f=1.0$ were obtained. Room porosity, vertical closure and horizontal closure histories are in excellent agreement over the simulated time (plotted to 2000 years) with and without contact surfaces. In fact, the SANTOS contact surface model is smoother than SANCHO as seen in Fig. 13, page C-123. SANTOS also models the gap between room roof and waste package top in a superior manner. Thus, SANTOS, which is faster and therefore more economical to run than SANCHO, was qualified for repository analyses through a series of benchmark analyses and comparisons in a process similar to that used for qualifying other creep codes, such as SPECTRUM, for possible WIPP use.

2) RD/VVP (Requirements Document/Verification and Validation Plan)

Requirements are outlined in Sections 2.0 and 3.0 of the Quality Assurance Document for SANTOS (Version 2.0.0). The 21 functional requirements described in Section 2.0 are those necessary for PA code usage. These include handling the two-dimensional, large displacement, finite strain, time-dependent response of salt and the inelastic response of other geologic media such as anhydrite. Modeling of contact surfaces is also a requirement as is the consolidation of porous materials. The latter differs from a conventional soil mechanics (porous geologic medium) consolidation process which requires a genuinely coupled material model. Compaction is a more apt description of this material model requirement that is intended for waste behavior.

The description of test cases, input files and acceptance criteria exercise all code portions required in the list of Section 2.0 (RD). However, specific acceptance criteria indicated in the VVP (page 9) as being in Sections 1 through 21 of the Verification and Qualification Document are not present. Acceptance criteria in this context are replaced by comparisons with known solutions or to solutions obtained independently by other computer codes. This approach is a conventional way of validating computer codes, that is, by a series of comparisons with known

analytical and numerical results that test various combinations of code options. There are no performance or attribute requirements for SANTOS relative to WIPP.

3) ID (Implementation Document)

Source code for SANTOS is not in the public domain; a source code listing is not provided for copyright security with an exception mentioned in Section 4.0 of the Quality Assurance Document for SANTOS (Version 2.0.0) on page 10.

EPA was provided with access to SANTOS for hands-on testing. In particular, the PA Version was compiled and run to repeat analysis of three test problems. The test problems were: Problem 20 of the V&QD document and two porosity surface calculations, one at a zero gas generation rate ($f=0.0$) and one at the standard rate of gas generation ($f=1.0$). All three were successfully executed. These problems required mesh generation and call back of input data files as well as compilation and execution of the SANTOS source code (Version 2.0.0). Thus, the proper version of SANTOS is available, can be compiled, and executes properly.

4) UM (User's Manual)

Functional requirements for SANTOS User's Manual are outlined in Section 5.0 of the Quality Assurance Document for SANTOS (Version 2.0.0). The SANTOS User's Manual is contained in PORSURF Attachment 7 (Docket: A-93-02, II-G-1, Volume XVI). The description of SANTOS is brief but efficient. A number of different material models are available, although only three are germane to the WIPP site. There is no discussion of alternatives to the choices presented. A trained user, one familiar with finite element analysis and related mechanics is required to run the code. Familiarity with the SNL computing system is also needed. Creation of an input data file is possible from the User's Manual description with the exception of the mesh data. The User's Manual does not address the question of mesh data format and how mesh data are read by SANTOS. In fact, the data are generated by FASTQ, a two-dimensional mesh generating program developed by SNL. Numerous other utility programs for reading, plotting, and similar functions are also accessed in the course of establishing an input data file and post-processing output. These programs and SANTOS itself are used for WIPP calculations but were not specifically developed for WIPP PA studies. Although the User's Manual is helpful in understanding the physical foundations of SANTOS, as a practical matter, SANTOS must be run at SNL with the guidance of an experienced user. While transport of an executable code copy, user training and off-site use is possible in principle, the process would be

time-consuming and costly.

5) VD (Validation Document)

Test information is referenced to the SANTOS - Verification and Qualification Document. Repeatability is ensured by the information and files supplied in the Validation Document and the DAT tapes. Appendix A of that document presents additional DAT information. Recent hands-on testing of three SANTOS problems produced output similar to the corresponding output in the VD. A Unix file comparison command revealed a single change in SANTOS. This change was in a constant used for numerical control, to prevent a zero divide. Specifically, the constant SRATIO was changed to $5.E-05 * G$ from $1.0E-05 * G$ where G is a shear modulus. This change did not affect results from any of the test problems. For example, Problem 20 was rerun at SNL from mesh generation through code execution and post-processing of selected output data. Examination of residual output information being generated during problem execution agreed precisely with the output sample data in the VD. Agreement with residuals in the solution of a nonlinear problem such as Problem 20 is a most severe test of repeatability that was successfully met in the course of this technical evaluation and qualification task. Similar results were obtained in the course of two porosity surface calculations which require three to four times more CPU time than Problem 20.

Such documentation shall include, but shall not be limited to:

c.1) Description of the theoretical backgrounds of each model and the method of analysis or assessment,

The SANTOS User's Manual meets this requirement which is an elaboration of the mathematical model background.

SANTOS is a two-dimensional, quasi-static, finite element computer program that allows for large deformation and finite strain. Creep of salt around a typical repository room will, in time, lead to large displacements and finite strains, so the capability for handling the kinematics of such is essential. The kinematics of large displacement, finite strain are integral to the mathematical model the underlies SANTOS (Section 2.1, SANTOS User's Manual). Closely linked to the kinematics of finite strain is the need for suitable measures of stress and strain rates, a question pursued with great interest in continuum mechanics and since resolved. This question is addressed compactly in Section 2.2 of the User's Manual. The requirements of stress equilibrium in the interior of a solid and at an interface, and

appropriate boundary conditions are presented in Section 2.3 of the User's Manual.

In addition to kinematics and equilibrium requirements, material laws are needed to form a complete mathematical model. SANTOS material laws or models, also known as constitutive equations, are described in Section 4.0 of the SANTOS User's Manual. The code is described as containing 12 material models ranging from a purely elastic model to time-dependent viscoplastic behavior. Eleven are implemented in SANTOS; apparently the twelfth may be provided by the user or else the interface "slide-line" is considered a material model. Only three are related to WIPP performance assessment; these generic models are the elastic-plastic, creep (deviatoric creep) and porous media consolidation (volumetric plasticity) which relate to anhydrite beds, salt formations and waste in rooms, respectively. The first and last are time-independent plasticity models, while the second is rate-dependent. All allow for separate deviatoric and volumetric strain treatment. In this regard, the sum of the stress transmitted in the solid skeleton and the fluid stress transmitted in the connected void space of porous materials is the stress required for equilibrium. The solid stress, which is the difference between total and fluid stress, is also known as the effective stress. It is the effective stress that is used in all constitutive models. However, this distinction is not intrinsic to any of the SANTOS constitutive models. SANTOS is used as a "dry" code for WIPP PA analyses. A dry code is in contrast to a "wet" code that allows for fluid flow as well as solid deformation.

The role of fluid stress, gas and brine pressure in rooms and adjacent strata, is handled on an improvised basis for PA purposes. In adjacent strata, total and effective stresses are considered to be the same; pore pressure is ignored. In rooms, void space and space occupied by solid waste are lumped into a ratio equated to *room porosity* rather than distributed through the waste as is physically the case. The solid fraction is held constant, although it is decomposition of the solid waste that generates gas. Also note, brine flow further complicates the room mass balance. The purpose of the code is to assist in calculating room void volume and thus to estimate room gas pressure in accordance with the ideal gas law that relates pressure to volume occupied at constant room temperature and given mass of gas. The mass of gas—i.e., the number of moles present depends on the rate of gas generation from waste decomposition. Room gas pressure and void space is important to BRAGFLO calculations. Indeed, this is the main role that SANTOS plays in the PA, providing room pressure and room void volume to BRAGFLO.

c.2) General descriptions of the models, discussions of the limits of the

applicability of each model, detailed instructions for executing the computer codes, including hardware and software requirements, input and output formats and explanations of each input and output variable and parameter (e.g., parameter name and units); listings of input and output files from a sample computer run; and reports on code verification, bench marking, validation, and quality assurance procedures.

SANTOS is limited to two-dimensional problems. The problem formulated for SANTOS is a vertical section through a typical room- or tunnel-like opening of rectangular cross-section in series of identical rooms separated by identical pillars and is therefore two-dimensional. The representation is reasonable in consideration of the small cross-sectional dimensions (room width and height) relative to room length. The two-dimensional limitation is therefore quite acceptable for such room and pillar analyses. Analysis of shaft deformation is also acceptable for the same reasons: the geometry of the excavation is sensibly two-dimensional in horizontal cross-section.

The creep model treats salt as a nonlinear viscoelastic fluid that flows until a hydrostatic state of stress is reached. Volumetric behavior is purely elastic. On a geological time scale and in consideration of salt domes and similar structures, the viscous fluid model seems reasonable. Whether the same model is applicable over an engineering time scale of only several hundreds of years is not clear. Total WIPP room closure is predicted in 100 years or so, depending on the various stratigraphic simplifications made. For example, inclusion of an anhydrite layer, in comparison with all salt stratigraphy, shows a 50% greater room volume (Docket: A-93-02, II-G-1, Volume XVI, Appendix PORSURF, Attachment 1, Fig.2, page 4) after 100 years.

The anhydrite material model uses Drucker-Prager yield, associated deviatoric plastic strain and elastic volumetric strain, somewhat similar to the strain decomposition of the salt creep model. In the latter, emphasis was placed on the use of a Tresca criterion which has corners on the yield surface. This emphasis was developed in consideration of measurements at the WIPP site. Whether an analogous situation occurs for anhydrite is open to question. An alternative would be to use a Mohr-Coulomb criterion that has edges rather than the smooth Drucker-Prager criterion. Drucker-Prager yield is convenient and physically appropriate to many rock types.

There is no report on SANTOS validation in the sense defined in the Introduction to the SANTOS - Verification and Qualification Document that requires

predictions from the code and the data measured in the field to be in agreement. There are papers in various symposia that describe such work. A very open technical dialogue has been maintained by publication of papers related to WIPP studies, but none are included in the CCA documents reviewed.

The creep closure conceptual model assumes that the rooms will creep to closure. Mechanical effects are local in extent, so model details and any limitations are ultimately not important to site undisturbed performance assessment. This view is endorsed by the Conceptual Model Peer Review Panel which noted certain limitations but agreed that the model is adequate.

Engineering analyses are always based on simplifying assumptions because not every detail is of great importance. Much of the engineering art is detecting when a model is overly simplified and a more complex model is needed. Even with the limitations noted, SANTOS computer run times may range to tens of hours on main frame computers. The reason lies in the many iterations needed for accommodating finite creep strains. Any benefit from an increase in complexity of existing models would have to be weighed against possible increases in run times. Current DOE opinion is that a coupled model that includes the simultaneous effects of pore pressure and solid strain is impractical.

Instructions for executing a SANTOS run including hardware and software requirements, input and output formats and a description of variables and parameters are contained in the User's Manual (Docket: A-93-02, II-G-1, Volume XVI, Appendix PORSURF, Attachment 7). SANTOS is written in Fortran-77.

Installation of an executable copy of SANTOS is a complicated process that requires a Unix platform and familiarity with software of the SNL ACCESS system. A Cray-J916 is the SNL hardware host.

Key words used in SANTOS input are described in Appendix A to PORSURF Attachment 7 (*ibid.*), which includes a description of control variables, boundary specifications, and material parameters required for 11 of the specified material models. Input is conveniently in free form. Output is described in Appendix C. Appendix E has several sample problems, although output is not given. However, there are many other sample problems in the SANTOS -Verification and Qualification Document that contain output.

Code validation is described in the SANTOS - Verification and Qualification Document in the form of 21 example problems complete with input data and sample output. The various examples exercise different features of SANTOS. In

this regard, the material model of porous media consolidation mentioned in the Requirements Document (RD) contained in the Quality Assurance Document for SANTOS (Version 2.0.0) is an ambiguous material model name. At first glance, one might assume this is the model for waste consolidation. However, it is actually the generic elastic-plastic model and is labeled SOILS N FOAMS in an input list. The only example problem that used this material model, according to the RD (page 8), is Problem 21 in the SANTOS - Verification and Qualification Document which involves a heated room that contains no waste. In fact, there are no sample problems that illustrate waste compaction, i.e., consolidation by room creep closure. However, such a problem exists in porosity surface calculations. The porosity surface calculation is described in Appendix PORSURF (Docket: A-93-02, II-G-1, Volume XVI).

c.3) Detailed descriptions of the structure of computer codes and complete listings of the source codes,

Protection of the commercial value of SANTOS precludes distribution of the source code listing without an appropriate agreement, but an exception was made for QA purposes as mentioned in the VVP (page 9) and noted above (ID). Details concerning the code structure are not readily available.

c.4) Detailed descriptions of data collection procedures, sources of data, data reduction and analysis, and code input parameter development,

Properties input for porosity surface calculations are listed in PORSURF Attachment 1 (*ibid.*) where the statement is made that the property values are the best estimates based on WIPP project documents, contractor reports, scoping analyses and analyses insights.

In this regard, there are some properties that may be derived from measured or other given properties. An example is the set of elastic properties in Table 1, page 6, of PORSURF Attachment 1 (*ibid.*) where Young's modulus, shear modulus and Poisson's ratio are tabulated. Only two of these properties are independent; the third may be computed from the first two, as is well-known in isotropic elasticity theory.

c.5) Any necessary licenses,

SANTOS is the property of SNL and is not in the public domain, so no license is required by DOE (SNL).

c.6) An explanation of the manner in which models and computer codes

incorporate the effects of parameter correlation.

The input parameters are independent material properties which may have a loose physical correlation. For example, a high Young's modulus may be expected to associate with a high compressive strength. However, no defined parameter correlations are included.

d) The Administrator or the Administrator's authorized representative may verify results of computer simulations used to support any compliance application by performing independent simulations. Data files, source codes, executable versions of computer software for each model, other material or information needed to permit the Administrator or the Administrator's authorized representative to perform independent simulations, and access to necessary hardware to perform such simulations, shall be provided within 30 calendar days of a request by the Administrator or the Administrator's authorized representative.

Three test problems were analyzed at SNL for the purpose of technical verification. These hands-on analyses were done with the assistance of SNL personnel who are familiar and have access to the SNL CRAY computer system. The three problems were: 1) Problem 20 - Isothermal WIPP Parallel Calculation, 2) porosity surface analysis at a zero gas generation rate, $f=0.0$ and 3) porosity surface analysis at the standard gas generation rate, $f=1.0$.

Problem 20 is described in detail in the SANTOS Verification and Qualification Document, pages 20-1 through 20-8, and in Appendix T-Input/Output Data for Problem 20 - Isothermal WIPP Parallel Calculation, pages T-1 through T-32. Output data are listed on pages T-19 through T-32. Output data obtained during the verification run and contained in Attachment

A3-1 (Problem 20) of this report are identical to the CCA data with the exception of small differences in central processing unit (CPU) time. These small differences are due to machine processing features involved with system queuing, etc. and have no effect on the results of the analysis.

Plots of vertical closure (relative displacement between roof and floor centerlines) and horizontal displacement versus time are presented in the V&QD, Figs. 20.5 and 20.6, respectively. These plots also show the results obtained by ANSALT and SANCHO. The SANTOS vertical room closure after 10 years is 0.279 m; horizontal displacement of the rib (room side) center is 0.195 m. Plots of the same data obtained from the verification analysis and shown in Attachment A3-1 of the

Appendix A3 (Problem 20) show the same results. Annotation of the plots in the Appendix A3 also indicates that utility programs ALGEBRA and BLOT were used to construct the plots from SANTOS output. These results confirm repeatability of SANTOS with respect to the V&QD Problem 20.

The second verification problem is an analysis of room closure with waste but without backfill and involves a simulated time span of 10,000 years. After the room is sealed, gas pressure is generated through waste decomposition that affects the room closure rate. Gas pressure generation is characterized by a parameter f . Values of this parameter range from 0.0 to 2.0. A value of 0.0 corresponds to no pressure generation; a value of 1.0 is considered the base case. This second verification problem involves $f=0.0$, that is, no gas pressure build-up in the rooms. Detailed output data for this problem are not presented in the CCA. However, the important information in the form of histories of room porosity and gas pressure are available in the Appendix PORSURF, Figs. 3 and 4, pages 11 and 13, respectively (Docket: A-93-02, II-G-1, Volume XVI). In the case of no gas pressure generation, the plot coincides with the x-axis and no curve is to be seen. The 10,000 year room porosity history in Fig. 3 starts at nearly 0.85, which is difficult to see on the plot because of the steep fall off with time at the beginning. After 10,000 yrs, the porosity decreases to about 0.205. The plot of the same porosity history shown in Attachment 2 of this report (Porosity Surface, $f=0.0$) indicates a somewhat higher porosity at 10,000 yrs, approximately 0.235. The difference may be caused by graphical errors developed in the publishing process. In this regard, there is a small typographical error in Figure PORSURF-3. (Fig. 3); the label of $f=1.8$ should be $f=0.8$. A gas generation rate of 1.8 was not used, but an 0.8 rate was, as explained in the text.

Verification data for the case of a gas generation rate of 1.0 are given in Attachment 3 (Porosity Surface, $f=1.0$) of this report. Starting porosities appear to be the same, as before. Again, the porosities at 10,000 yrs are slightly different. Fig. 3 in Appendix PORSURF indicates a porosity of about 0.71 while the verification run result is about 0.73. The reason for this small difference is unknown and may be simply plotting accuracy. Gas pressure at 10,000 yrs in Appendix PORSURF (Fig. 4) is about 17.0 MPa and in the verification run, about 17.5 MPa. This difference is consistent with the observed porosity difference.

REFERENCES

See Appendix B(4) for a listing of docketed references.

ATTACHMENT A3-1 - Problem 20

This attachment contains a sampling of output data obtained from a rerun of Problem 20 - Isothermal WIPP Parallel Calculation that is described in APPENDIX T of the SANTOS - Verification and Qualification Document. Comparisons show the outputs are in agreement with the exception of small differences in CPU time. These differences serve the useful purpose of demonstrating the fact that a rerun was actually done. This appendix also contains plots of horizontal and vertical room closure which are in agreement with previous results (Figs. 20.5 and 20.6, pg 20-7, SANTOS - Verification and Qualification Document).

The remainder of this attachment is not available electronically

ATTACHMENT A3-2 - Plot of Porosity History

Not available electronically

ATTACHMENT A3-3 - Verification Data for Gas Generation Rate of 1.0

Not available electronically

APPENDIX A4 CUTTINGS_S COMPUTER CODE EVALUATION

The CUTTINGS_S computer code estimates short term releases of radioactivity to the land surface in the event that an inadvertent drilling intrusion penetrates waste in the WIPP repository. CUTTINGS_S considers three release mechanisms: *cuttings*, the volume of waste directly intercepted by the drill bit; *cavings*, additional waste removed from the borehole wall by erosion of the drilling fluid as it exits the drill bit and flows through the annulus between the drill collar and the borehole wall; and *spallings*, waste expelled from the borehole if the pressure in the repository exceeds about 8 MPa. Cuttings and cavings releases are adjusted based on the volume-based probability that specific waste streams are intercepted by the drill bit.

EPA REVIEW

a) Any compliance application shall include:

a.1) A description of the conceptual models and scenario construction used to support any compliance application

The conceptual model is described in the User's Manual (UM) (Docket: A-93-02, II-G-1, Volume V, Appendix CUTTINGS). The manual provides a description of the conceptual and mathematical models used in the CCA to predict direct removal of waste from oil and gas well drilling operations. The *cuttings* model is derived from a simple exercise in geometry as the removed waste is represented by a *cookie-cutter* section based on an ideal area calculated using the drill bit diameter.

The *cavings* model is derived from fluid flow equations developed to optimize the rheological properties of drilling mud. These fluid flow equations were developed as a practical guide to adjust fluid properties to maintain the gauge of the bore, minimize drilling time, and enhance safety.

Two *spallings* models are presented in the UM. Model 1 predicts waste will erode from the surfaces of an increasing void space around the drill hole from excess pressure in the waste. Model 2 uses a refined model based on bench scale experiments involving fine grained silicas to predict waste erosion from fracture surfaces which is created when the drill bit first punctures a pressurized waste repository.

a.2) A description of plausible alternative conceptual model(s) seriously considered but not used to support such application, and an explanation of the reason(s) why such model(s) was not deemed to accurately portray performance of the disposal system.

The Conceptual Models Peer Review Panel (CMPRP) concluded that "There are no meaningful alternatives for the cuttings and cavings model, except perhaps to consider using a finite fixed assumed input value, which would be more arbitrary." (Docket: A-93-02, II-G-1, Volume XII, Appendix PEER, PEER 1, Section 3.13.2.3).

Appendix MASS, Section MASS.16.1.1 (*ibid.*, Volume X) provides limited discussions of the progression of the spallings model to incorporate experimental information in refining the conceptual model for this aspect of the CUTTINGS_S code. Because the spallings conceptual model is judged to be inadequate by the CMPRP, DOE developed an alternative mechanistically based model which demonstrated that the spallings model used in the CCA produces conservative results (Docket: A-93-02, II-G-23).

a.3) Documentation that:

a.3.i) conceptual models and scenarios reasonably represent possible future states

of the disposal system.

The conceptual models are based on standard drilling practices for the region surrounding the WIPP site. Section 194.33(c)(1) states “Future drilling practices and technology will be remain consistent with practices in the Delaware basin at the time a compliance application is prepared.” Based on this, the CCA meets this requirement.

Section 5.0 of the User’s Manual explicitly states the CUTTINGS_S code is based on present-day drilling methods and technologies that apply at a WIPP-like site, but cautions against application of the code for parameter ranges that are atypical of the WIPP and its immediate environs.

a.3.ii) mathematical models incorporate equations and boundary conditions which reasonably represent the mathematical formulation of the conceptual models.

The CUTTINGS_S UM presents the mathematical models used to implement the conceptual models. The UM provides a discussions of boundary conditions related to permeability and pressures which govern selection of appropriate models, e.g. spallings occurs only when the repository pressure exceeds 8 MPa.

Equation 18 of the UM presents the equation used to calculate a critical borehole radius. In an eroding borehole, an increase in the well bore diameter results in a decreasing Reynolds number. For an initially turbulent flow, a check is made at the final eroded radius to determine if the flow at that radius is still within the turbulent regime. If it is not, equation 18 is used to calculate a borehole radius corresponding to the Reynolds number of 2100—which is the cross over point in the model between turbulent and laminar flow regimes. The laminar flow solution is then started at this critical radius and continued to final eroded radius.

Equation 14, the pressure loss in an annulus, uses a general equation found on page 27 in Broc 1982. A more specific equation for calculating pressure loss in an annulus subject to turbulent flow also appears on that same page in Broc. Broc also presents an empirical relation between the friction factor, f , and the Reynolds number, N_{Re} :

$$f = 0.05 / N_{Re}^{0.2}$$

DOE chose to use a derivation for the friction factor, f , from Whittaker 1985 to relate the friction factor to the Reynolds number and relative roughness. Hand calculations suggest no significant differences between the two factors. In fact, the

solution used by DOE is more rigorous since it accounts for the influence of surface roughness in calculating the friction factor.

a.3.iii) numerical models provide numerical schemes which enable the mathematical models to obtain stable solutions.

The code uses a numerical technique to solve for the derivative of shear stress with respect to radius for small assumed changes in radius. Based on its review the EPA determined the numerical methods used is adequate for use in the CCA PA and produces stable solutions as used in the CCA PA.

a.3.iv) computer models accurately implement the numerical models; i.e., computer codes are free of coding errors and produce stable solutions.

EPA conducted a sensitivity analysis on the CUTTINGS_S code using ranges of variables cited in the UM. 100 Latin Hypercube Sampling (LHS) samples were generated and run through CUTTINGS_S to generate a response surface map. Three of these runs (Cases 45, 57, and 78) failed to reach convergence because of particular parameter combinations.

To investigate this potential non-convergence problem, the DRILL subroutine—including all subroutines and functions called by DRILL—were extracted from CUTTINGS and compiled for the PC with Lahey FORTRAN 90. A driver routine was written to *feed* the parameters for the 100 cases to DRILL. When the 100 cases were run on the PC, only 93 cases ran to completion. In addition to the three cases above, Cases 34, 61, 71, and 88 did not converge.

The non-convergence problem was traced to the following line of code near the end of the INTERFACE subroutine:

```
IF(ABS(TREY-2100.).GT.1.0)GOTO 912
```

When there is turbulent flow, the INTERFACE subroutine is called by DRILL to calculate a multiplier of the linear velocity. All 100 cases were made to run to completion by changing the above line of code to:

```
IF(ABS(TREY-2100.).GT.1.0 .and. abs(treyold-2100.).gt.1.0  
+.and. abs(treyold-trey).gt.1.0)GOTO 912
```

As shown in Table A4-1, even with this change there is good agreement between the DEC and the PC results (*i.e.*, the ratio of the DEC results (area_c) to the PC results (xnewarea) ranged from 0.983 to 1.015 with an average ratio for all cases of

1.000).

Table A4-1. Summary of Sampled Parameters and Comparison of DEC and PC Results. Note that cases 34, 45, 57, 61, 71, 78, and 88 are summarized at the end of the table.

Case	DIAMMOD	DOMEGA	TAUFAIL	DENSITY	ABSRROUGH	VISCO	YLDSTRSS	area_c	xnew
1	0.29	9.46	0.188	1169	0.014	0.01	15.98	0.39539	0.3
2	0.32	4.4	0.647	1160	0.02	0.012	10.01	0.20083	0.19
3	0.3	20.39	0.097	1226	0.03	0.017	11.04	0.55239	0.54
4	0.32	8	3.401	1220	0.022	0.01	9.158	0.15281	0.15
5	0.32	6.19	0.536	1305	0.013	0.017	3.904	0.21472	0.21
6	0.43	5.2	0.059	1261	0.023	0.024	12.74	0.61777	0.62
7	0.42	16.11	1.182	1295	0.02	0.011	5.919	0.32374	0.32
8	0.3	22.68	0.261	1257	0.021	0.011	16.29	0.51483	0.51
9	0.36	18.33	0.103	1302	0.035	0.023	16.36	0.60772	0.60
10	0.39	7.7	0.19	1149	0.019	0.015	7.498	0.39598	0.39
11	0.34	14.79	0.076	1336	0.019	0.01	3.446	0.94104	0.9
12	0.28	17.11	2.368	1181	0.026	0.025	6.142	0.10583	0.10
13	0.44	12.84	7.926	1246	0.033	0.013	3.234	0.14945	0.15
14	0.34	4.2	0.053	1158	0.03	0.01	10.84	0.6708	0.66
15	0.29	20.64	0.215	1161	0.031	0.01	9.381	0.66082	0.6
16	0.41	11.58	4.214	1242	0.014	0.01	6.642	0.18361	0.18
17	0.33	17.71	0.567	1210	0.011	0.01	5.081	0.37478	0.37
18	0.37	22.95	1.855	1141	0.013	0.012	8.281	0.2345	0.23
19	0.35	6.27	1.666	1217	0.021	0.01	18.84	0.20808	0.20
20	0.42	8.35	3.477	1220	0.027	0.018	16.54	0.14556	0.14
21	0.41	8.59	1.135	1238	0.036	0.022	17.82	0.20072	0.20
22	0.28	10.38	5.826	1364	0.029	0.025	17.04	0.09056	0.08
23	0.28	22.35	8.998	1211	0.033	0.02	5.447	0.09258	0.09

Case	DIAMMOD	DOMEGA	TAUFAIL	DENSITY	ABSROUGH	VISCO	YLDSTRSS	area_c	xnewa
24	0.31	17.34	0.103	1193	0.027	0.021	12.61	0.54272	0.54
25	0.34	15.56	0.868	1176	0.039	0.01	8.175	0.36011	0.36
26	0.4	6.49	0.123	1203	0.012	0.023	19.08	0.41526	0.41
27	0.42	20.33	0.201	1224	0.039	0.01	17.37	0.81209	0.81
28	0.34	13.88	8.3	1299	0.019	0.01	8.52	0.15298	0.15
29	0.35	18.88	0.162	1318	0.026	0.012	2.947	0.70063	0.70
30	0.38	10.54	0.16	1346	0.038	0.01	15.24	0.73733	0.73
31	0.43	13.34	7.661	1335	0.039	0.018	9.545	0.14719	0.14
32	0.41	16.01	0.105	1204	0.017	0.022	14.21	0.58607	0.
33	0.37	4.75	0.112	1272	0.025	0.01	3.247	0.54316	0.54
35	0.39	19.51	4.441	1267	0.015	0.01	11.57	0.20991	0.21
36	0.36	22.23	2.102	1326	0.038	0.015	7.08	0.2469	0.24
37	0.29	11.34	0.118	1231	0.016	0.017	18.64	0.40081	0.40
38	0.28	14.63	4.589	1199	0.028	0.01	10.28	0.13995	0.14
39	0.36	7.18	0.742	1183	0.033	0.029	10.8	0.17244	0.17
40	0.36	8.96	0.077	1339	0.028	0.014	10.63	0.6827	0.67
41	0.33	21.94	0.09	1260	0.034	0.02	18.5	0.70268	0.70
42	0.33	19.8	0.306	1315	0.024	0.01	13.11	0.57978	0.58
43	0.44	9.82	1.404	1311	0.036	0.028	8.681	0.19261	0.19
44	0.35	18.07	0.329	1200	0.015	0.026	4.538	0.27421	0.27
46	0.28	15.75	1.628	1247	0.023	0.03	4.186	0.10829	0.10
47	0.29	5.37	2.758	1151	0.037	0.029	4.71	0.09235	0.09
48	0.31	5.99	0.069	1357	0.015	0.01	16.92	0.72682	0.72
49	0.4	21.09	0.247	1234	0.018	0.014	12.03	0.58254	0.58
50	0.39	12.93	1.78	1236	0.028	0.027	5.624	0.15513	0.15
51	0.36	10.74	0.447	1189	0.022	0.014	11.47	0.30698	0.30
52	0.43	12.32	0.429	1215	0.032	0.01	2.407	0.53936	0.54

Case	DIAMMOD	DOMEGA	TAUFAIL	DENSITY	ABSROUGH	VISCO	YLDSTRSS	area_c	xnewa
53	0.37	7.43	2.396	1377	0.027	0.013	14.74	0.17917	0.17
54	0.29	13.13	4.008	1244	0.034	0.01	4.819	0.18165	0.17
55	0.43	20.02	0.602	1196	0.03	0.015	2.823	0.40285	0.40
56	0.35	15.11	0.065	1323	0.025	0.01	10.31	1.0696	1.
58	0.38	18.69	0.229	1341	0.017	0.023	16.68	0.42937	0.43
59	0.29	17.86	0.94	1144	0.037	0.027	11.96	0.13777	0.13
60	0.32	15.03	4.853	1290	0.01	0.013	6.93	0.13187	0.13
62	0.44	16.97	0.41	1299	0.014	0.021	7.256	0.39054	0.38
63	0.44	14.48	0.377	1206	0.021	0.01	8.815	0.5508	0.54
64	0.3	12.64	0.135	1281	0.02	0.017	9.079	0.42243	0.42
65	0.37	9.49	0.612	1250	0.038	0.01	8.069	0.38957	0.38
66	0.41	10.92	3.757	1342	0.029	0.016	12.29	0.16788	0.16
67	0.33	21.6	1.943	1354	0.017	0.019	6.049	0.18933	0.18
68	0.27	8.85	0.173	1329	0.04	0.012	11.71	0.38944	0.38
69	0.37	12.08	1.048	1288	0.036	0.011	11.24	0.29638	0.29
70	0.32	19.12	3.053	1293	0.025	0.01	15.54	0.22368	0.
72	0.3	18.63	7.013	1370	0.013	0.01	15.12	0.14237	0.14
73	0.31	11.72	0.086	1353	0.022	0.019	14.58	0.51215	0.51
74	0.35	6.77	0.888	1332	0.011	0.011	14.42	0.22336	0.2
75	0.42	19.32	0.753	1361	0.032	0.01	19	0.52762	0.52
76	0.4	21.44	0.057	1348	0.031	0.016	6.389	1.1641	1.1
77	0.3	20.8	5.156	1252	0.035	0.01	13.25	0.20801	0.20
79	0.43	17.44	0.082	1318	0.024	0.019	14.94	0.87606	0.86
80	0.38	9.94	0.987	1274	0.029	0.012	2.711	0.26928	0.26
81	0.38	14.04	0.051	1144	0.037	0.01	12.89	1.2923	1.2
82	0.42	13.56	6.194	1165	0.023	0.016	17.89	0.13828	0.13
83	0.44	15.34	8.955	1360	0.031	0.01	5.364	0.1747	0.17

Case	DIAMMOD	DOMEGA	TAUFAIL	DENSITY	ABSROUGH	VISCO	YLDSTRSS	area_c	xnewi
84	0.4	19.83	0.15	1148	0.016	0.01	14.04	0.7562	0.75
85	0.31	4.97	6.292	1228	0.015	0.01	7.418	0.10866	0.10
86	0.27	8.32	3.187	1307	0.038	0.01	7.609	0.14894	0.14
87	0.42	5.59	0.464	1155	0.012	0.014	3.922	0.27128	0.26
89	0.38	18.24	0.363	1366	0.018	0.01	9.822	0.627	0.63
90	0.4	16.41	0.819	1264	0.018	0.024	17.64	0.23765	0.23
91	0.39	22.54	0.129	1175	0.024	0.014	18.15	0.75573	0.74
92	0.31	14.24	5.326	1165	0.032	0.01	17.28	0.17639	0.17
93	0.27	11.43	2.929	1172	0.023	0.021	13.9	0.10097	0.10
94	0.28	4.95	0.062	1373	0.016	0.028	6.492	0.53635	0.53
95	0.39	6.87	2.591	1178	0.025	0.02	15.5	0.13758	0.13
96	0.34	12.14	0.275	1351	0.029	0.01	3.69	0.59407	0.59
97	0.27	21.14	0.14	1278	0.019	0.012	4.357	0.55086	0.55
98	0.43	5.88	0.493	1268	0.035	0.018	13.35	0.29353	0.29
99	0.3	11.04	0.678	1372	0.031	0.026	15.76	0.18297	0.18
100	0.33	9.26	6.844	1254	0.011	0.01	16.05	0.12824	0.12
34	0.35	7.9	0.288	1190	0.034	0.01	13.6	0.48462	0.48
61	0.41	16.74	1.242	1311	0.016	0.01	7.941	0.36033	0.36
71	0.34	10.17	1.558	1321	0.04	0.01	9.682	0.29697	0.29
88	0.41	21.83	0.233	1283	0.011	0.01	12.4	0.70952	0.70
45	0.384	13.67	2.26	1186	0.035	0.01	18.2	DNCR	0.2
57	0.36	7.309	0.346	1276	0.026	0.01	13.8	DNCR	0.44
78	0.32	16.5	1.31	1287	0.011	0.01	5.18	DNCR	0.29
Min	0.27	4.2	0.051	1141	0.01	0.01	2.407	0.09056	0.08
Max	0.44	22.95	8.998	1377	0.04	0.03	19.08	1.2923	1.2
Avg	0.3556	13.604	1.7719	1258.4	0.025	0.014	10.804	0.388494	0.387

No convergence problems appeared with this code when running the DOE verification tests or in operating the code during a variety of other tests in the course of the EPA review. Since convergence problems were not experienced during normal use of the code, no changes to the source code are required.

a.3.v) conceptual models have undergone peer review according to § 194.27.

The Conceptual Model Peer Review Panel (CMPRP) approved the conceptual models for cuttings/cavings but initially rejected the spillings model. The spillings sub-model was subsequently reviewed by the CMPRP on three additional occasions. While the CMPRP was not satisfied with the spillings model, based on significant additional data provided by DOE

(Docket: A-93-02, II-G-23), they concluded that the model provided conservative results and that actual spillings releases would likely be less than calculated with the spillings sub-model.

b) *Computer codes used to support any compliance application shall be documented in a manner that complies with the requirements of ASME NQA-2a-1990 addenda, part 2.7, to ASME NQA-2-1989 edition.*
(Incorporation by reference as specified in § 194.5)

The Requirements Document/Validation & Verification Plan (RD/VVP) (Docket: A-93-02, II- G-3, Volume 4) presents four functional requirements and 12 external interface requirements for the CUTTINGS_S code. These requirements are adequate for the usage of CUTTINGS_S in the CCA PA calculations. The RD/VVP also describes model functionality that is not tested and provides adequate documentation as to why this functionality is not tested.

The User's Manual provides sufficient information to exercise the CUTTINGS_S. The technical basis for the code is well written and understandable. The math can be easily followed for most of the document. Equations were cross checked against source documents and no inconsistencies were found.

Each of the input files is presented and described in the User's Manual (UM). In addition, the Validation Document (VD) (Docket: A-93-02, II-G-3, Volume 4) presents source listings of input and outputs files for each test case and documents that the tests met the acceptance criteria.

c) *Documentation of all models and computer codes are included as part of any compliance application performance assessment calculation*

shall be provided. Such documentation shall include, but not be limited to:

c.1) Description of the theoretical backgrounds of each model and the method of analysis or assessment,

The UM provides an adequate description of the theoretical background of the CUTTINGS_S computer code.

c.2) General descriptions of the models; discussions of the limits of applicability of each model; detailed instructions for executing the computer codes, including hardware and software requirements, input and output formats with explanations of each input and output variable and parameter (e.g., parameter name and units); listings of input and output files from a sample computer run; and reports on code verification, benchmarking, validation, and quality assurance procedures.

Discussion of the limits of applicability of the models is contained in Section 5.0 of the UM and appears to be complete. Detailed instructions for executing the computer code are also contained in the User's Manual. The information is complete and accurate. Listings of input and output files from a sample computer run are contained in Sections 7 and 9 of the UM, respectively. The analysis plans, RD/VVP, and VD provide the required documentation on code verification, benchmarking, validation, and quality assurance procedures.

c.3) Detailed descriptions of the structure of computer codes and complete listings of the source codes;

A complete listing of the source code is contained in the Implementation Document. The description of the structure of the code is adequate.

c.4) Detailed descriptions of data collection procedures, sources of data, data reduction and analysis, and code input parameter development.

Details of the data collection procedures, sources of data, data reduction and analysis and code input parameter development are discussed in the Technical Support Document for Section 194.23: Parameter Report (Docket: A-93-02, III-B-12).

c.5) Any necessary licenses;

No licenses were required for CUTTINGS_S. The code was produced specifically for the CCA.

c.6) An explanation of the manner in which models and computer codes incorporate the effects of parameter correlation.

No correlated parameters were included as input to the CUTTINGS_S code.

d) The Administrator or the Administrator's authorized representative may verify results of computer simulations used to support any compliance application by performing independent simulations. Data files, source codes, executable versions of computer software for each model, other material or information needed to permit the Administrator or the Administrator's authorized representative to perform independent simulations, and access to necessary hardware to perform such simulations, shall be provided within 30 calendar days of a request by the Administrator or the Administrator's authorized representative.

DOE identified appropriate contacts and provided the documentation required by EPA for its review of this code.

ATTACHMENT A4-A DOCUMENTATION OF CUTTINGS_S TEST RUNS

EPA conducted tests of the CUTTINGS_S code to accomplish the following:

1. Verify ability to run the model.
2. Verify ability to reproduce Validation & Verification (VV) runs.
3. Exercise models to evaluate parameter sensitivity that was not documented in the CCA.

EPA conducted these tests on the Sandia WIPP cluster in the EPA section on the Sandia VAX environment. Input files and executables were obtained by fetching these files from the CCA-CMS CUSP library. The tests are described below.

Test 1 - Verification of VV Runs

The RD/VVD for CUTTINGS_S presents the approach used to verify the code by running the same data through the CCA production model and the simplified validation codes. The results from the verification tests were compared and evaluated to determine if the acceptance criteria were met. EPA was able to re-run the test. The output file generated by the EPA test run was compared against the output of the DOE test runs stored in the CUSP CCA-CMS library. The VMS DIFFERENCE command was used to compare the output files and other than dates no differences were noted. This demonstrates that the DOE VV exercise was

reproducible.

Test 2 - Generation of Response Surface Map

Parameter distributions are presented in the UM for eight separate variables in the cuttings/cavings model (pages 48-49). In the CCA, the only variable defined by a probability distribution is erosion shear resistance (TAUFAIL). A new run was configured to exercise the CUTTINGS_S code substituting probability distributions for seven of eight parameter distributions listed in the CUTTINGS_S UM. These distributions are listed in Table A4.2

Table A4.2. Input Distributions for Cuttings/Cavings Variables Used in EPA Sensitivity Analysis

Variable		Distribution Type	Upper	Lower
TAUFAIL	Erosion Shear Resistance (Pa)	Loguniform	0.05	10
DOMEGA	Drill String Angular Velocity (rad/s)	Uniform	4.2	23
DNSFLUID	Drilling mud density (kg/m ³)	Uniform	1139.	1378.
VISCO	Bingham plastic viscosity (Pa s)	Loguniform	0.005	0.03
YLDSTRSS	Bingham yield stress (Pa)	Uniform	2.4	19.2
ABSROUGH	Absolute roughness (m)	Uniform	0.01	0.04
DIAMMOD	Drill bit diameter (m)	Uniform	0.267	0.444

The VMS script EVAL_CUSP_RUN.COM was executed to run GENMESH, MATSET, PRELHS, and LHS to create 100 CDB input files for CUTTINGS_S. Input file scripts were created for each sample and a VMS script was written to submit all 100 LHS samples through CUTTINGS_S in batch mode on the Sandia WIPP cluster. Three of these runs were terminated after running for 12 hours each. Typical CPU times for the other 97 runs were 3 minutes.

Once the remaining 97 batch runs were completed, the input and output data were extracted from the binary output files using a script which automated the extraction process using the GROPE command. Ninety-seven text files were created from this extraction process and summarized into a final text file,

CUSP_MVM_GROPE_ALL.SEA. This data file was downloaded from the WIPP cluster and the raw data was extracted and converted into a database file. Using a PC based statistical package, SIMSTAT, descriptive summaries of the data were produced and are presented in Table A4.3. A rank regression analysis was performed on the response surface map to evaluate sensitivity of the input variables. The rank regression analysis results are presented below:

$$\text{AREA_C} = 81.3550 + (.2002 * \text{DIAMMOD}) + (.2175 * \text{DOMEGA}) + (-.8990 * \text{TAUFAIL}) + (.08065 * \text{DENSITY}) + (.03710 * \text{ABSROUGH}) + (-.3057 * \text{VISCO}) + (.008979 * \text{YLDSTRSS})$$

where AREA_C is the area of the eroded borehole. Table A4.3 provides additional information on the regression analysis coefficients (B) including the standard error and confidence limits (CL).

Table A4.3. Limits on Regression Analysis Variables

Variable	B	Std Error B	Upper 95% CL	Lower 95% CL
Intercept	81.8346			
TAUFAIL	-.8990	.01408	-.9269	-.8710
VISCO	-.3057	.01394	-.3334	-.2780
DOMEGA	.2175	.01390	.1899	.2451
DIAMMOD	.2002	.01393	.1725	.2278
DENSITY	.08065	.01390	.0535	.1082
ABSROUGH	.03710	.01392	.009467	.06474
YLDSTRSS	.008979	.01398	-.01878	.03674

These results as defined in Table A4.3 demonstrate that erosion shear resistance, TAUFAIL, is the dominant influence on cavings area. Bingham plastic viscosity, drill string angular rotation, and drill bit diameter also had significant (>20 %) influence on cavings area. This is illustrated in the scatter plot below (Figure A4.1) where the relationship between TAUFAIL and cavings area is not the same monatomic function as presented in Figure 11 of the Analysis Package for Cuttings and Spalling Calculations (Docket: A-93-02, II-G-06). The minimum cavings area

quoted in the Analysis Package of approximately 0.1 m² is in close agreement with the minimum of 0.09 m² calculated here. Both values are only slightly greater than the drill bit area of 0.076 m². However, the maximum area reported in the Analysis Package is approximately 0.73 m² while the maximum area determined in this sensitivity analysis is 1.3 m².

Data summarizing the LHS runs are included in Table A4.4. Note that for this analysis a log uniform distribution was assumed for TAUFAIL while a uniform distribution is assumed in the CCA. Thus, the median value for this parameter in the CCA is 5 Pa while in this study the median is 0.61 Pa.

During the Agency’s parameter review (A-93-02, III-B-12, III-B-13 and III-B-14(5)) TAUFAIL, VISCO, DOMEGA, DIAMMOD, DENSITY, ABSROUGH, and YLDSTRSS were evaluated because of the results of this review. The EPA found that, except for TAUFAIL, the values used in the CCA PA calculations were reasonable, appropriate and adequate.

Figure A4.1. Variability in Eroded Borehole Area as Function of Waste Erosion Shear Resistance

Table A4.4. Summary of Results of Uncertainty Analysis

Percentile	Cavings Area	Waste Strength	Drilling Mud Density	Drill Collar Absolute Roughness	Drilling Mud Viscosity	Drilling Mud Yield Stress	Drill Bit Diameter	Drill String Angular Velocity
Min	.09	.05	1141.	.01	.01	2.41	.27	4.2
10	.14	.08	1161.	.01	.01	3.92	.28	5.9
20	.15	.13	1187.	.02	.01	5.8	.30	7.9
30	.19	.21	1210.	.02	.01	7.45	.32	9.8
40	.23	.37	1234.	.02	.01	9.09	.34	11.6
50	.31	.61	1257.	.02	.01	10.8	.35	13.2
60	.40	1.04	1283.	.03	.02	12.38	.37	15.2
70	.54	1.91	1309.	.03	.02	14.14	.39	17.6
80	.60	3.43	1333.	.03	.02	15.85	.41	19.4
90	.73	5.9	1354.	.04	.03	17.42	.43	21.2
Max	1.29	9.0	1377.	.04	.03	19.08	.44	22.9
AVG	.39	1.79	1259.	.03	.01	10.75	.36	13.6

REFERENCES

Broc, R., ed. 1982. *Drilling Mud and Cement Slurry Rheology Manual*, Houston, TX: Gulf Publishing Company

Whittaker, A., ed. 1985. *Theory and Application of Drilling Fluid Hydraulics*, International Human Resources Development Corporation, Boston, MA.

See Appendix B for listing of docketed references.

APPENDIX A5 CCDFGF COMPUTER CODE EVALUATION

Appendix B to 40 CFR Part 191 contains the following guidance for performance assessment models used to evaluate waste disposal systems:

The Agency assumes that, whenever practicable, the implementing agency will assemble all of the results of the performance assessments to determine compliance with 191.13 into a *complementary cumulative distribution function* that indicates the probability of exceeding various levels of cumulative release.

Additional guidance is provided in Appendix A to 40 Part CFR 191 where the primary measure of the consequence, or seriousness, of a release resulting from an intrusion is defined as the *cumulative normalized release* that occurs over the 10,000 years following closure of the repository. Specific procedures for calculating the cumulative normalized release are defined in Appendix A, Table 1 of the rule. Applicable release limits for the WIPP are to be calculated based on the total curies of transuranic activity placed in the disposal system at the time of closure.

The release limits are defined in terms of probabilities at §191.13.

Disposal systems for spent nuclear fuel or high-level or transuranic radioactive wastes shall be designed to provide a reasonable expectation, based upon performance assessments, that cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal from all significant processes and events that may affect the disposal system shall:

(1) Have a likelihood of less than one chance in 10 of exceeding the quantities calculated according to Table 1 (Appendix A); and

(2) Have a likelihood of less than one chance in 1,000 of exceeding ten times the quantities calculated according to Table 1 (Appendix A).

Note that the release limits (1) and (2) are defined in terms of probabilities. Each estimated Complementary Cumulative Distribution Function (CCDF) provides a probability distribution of the possible values for R, the summed normalized release defined in Appendix A of the rule for use of Table 1 quantities. The CCDF is a function of the cumulative normalized release (R). The estimated CCDF must comply with the following requirements.

- (1) $CCDF(R=1) < 0.1$ (less than one chance in 10 that $R > 1$), and
- (2) $CCDF(R=10) < 0.001$ (less than one chance in 1,000 that $R > 10$).

These requirements mean that the WIPP is *not* in compliance if there is a greater than 10 percent probability of occurrence of a normalized release, accumulated over 10,000 years, that is greater than 1. In addition, the site is not in compliance if there is a greater than 0.1 percent probability that the normalized release exceeds a value of 10.

The PA program CCDFGF is designed to calculate one CCDF for each Latin Hypercube Sample (LHS) vector of model parameters. The resulting mean CCDFs are compared, individually and collectively, to the established release limits.

Much of the information on which the EPA review of this code was based is contained in the QA Package for the CCDFGF computer code (Docket: A-93-02, II-G-03, Volumes 2 and 3). These volumes contain the following relevant documents:

UM - User's Manual for CCDFGF (Version 1.00)

DD - Design Document for CCDFGF and GRIDFLO

RD - Requirements Document for CCDFGF (Version 1.00)

ID - Implementation Document for CCDFGF (Version 1.00)

VVP - Verification and Validation Plan for CCDFGF (Version 1.00)

VD - Validation Document, Version 1.00

The Design Document is also included as Appendix CCDFGF (Docket: A-93-02, II-G-1, Volume V).

In the ensuing discussion these documents will be referred to by their generic title (i.e., User's Manual) or their generic abbreviation (i.e., UM). The detailed titles and docket references will not be repeated.

EPA REVIEW

a) Any compliance application shall include:

a.1) A description of the conceptual models and scenario construction used to support any compliance application.

Compliance calculations in the CCA CCDFGF program differ from calculations performed in the 1991 through 1994 PA documents. Substantive changes were made in the approach to simulation, the method for modeling multiple intrusions, and the treatment of brine encounters. Chapter 6 of the CCA (Docket: A-93-02, II-G-1, Volume I) provides a simplified discussion of the new approach designed to be accessible to readers not familiar with the WIPP PA methodology (pp. 6-11 to 6-35). Mathematical details of the new approach are described in the Design Document for CCDFGF, included as CCA Appendix CCDFGF (Docket: A-93-02, II-G-1, Volume V).

The application of CCDFs in determining compliance is addressed in the *Technical Support Document for 194.34* (Docket: A-93-02, III-B-23). A review of CCDFs and the requirements of 40 CFR 191 and 40 CFR 194 is summarized below.

Complementary Cumulative Distribution Functions

The FORTRAN code in the program CCDFGF is designed to calculate one Complementary Cumulative Distribution Function (CCDF) for each Latin Hypercube Sample (LHS) vector. The procedures for selecting LHS parameter values are discussed in Appendix A6 of this TSD. In the CCA, 57 parameters were selected for inclusion in the LHS procedures. In the EPA-mandated verification test, 60 parameters were assigned to the LHS (Docket: A-93-02, II-G-26). Calculations for cuttings, spallings, and direct brine releases are performed for a variety of conditions and selected times using other codes of the PA model. The calculations are performed for each of 100 LHS vectors. The entire procedure is run three times, with different random values selected for the parameters in each replicate. The 300 data sets are assembled into a single intermediate data file by the CCDFGF program when it is run in the preprocessor mode.

The normal mode of the CCDFGF program uses the release values tabulated by the preprocessor mode of the program to simulate future human intrusion scenarios.

The simulation for a single LHS vector in the CCA generated $N = 10,000$ simulated futures, each future consisting of a sequence of intrusion events occurring at random times over the next 10,000 years. Interpolation is used to estimate appropriate release values for each simulated intrusion.

The frequency distribution of the simulated cumulative releases over 10,000 years generates a single estimate of the CCDF. This procedure is repeated for each of the 100 LHS vectors. There are three replicates of the entire procedure. In each replicate, the 100 CCDFs are combined in the CCDFSUM program to generate summary CCDF curves, such as the sample mean, median, 10th, and 90th percentile CCDFs at each value of the release for the replicate. These calculations provide three point estimates for each type of summary CCDF curve at each value of the normalized release R , one point estimate from each replicate.

Table 1 of Appendix A of 40 CFR Part 191 provides numerical criteria for calculating the total normalized release of transuranic isotopes. The release limits (1) and (2) are defined in terms of probabilities. The estimated CCDFs provide a probability distribution of the possible values for R , the summed normalized release defined in Appendix A for use of Table 1 quantities. The estimated CCDF must comply with the following requirements.

- (1) $CCDF(R=1) < 0.1$ (less than one chance in 10 that $R > 1$), and
- (2) $CCDF(R=10) < 0.001$ (less than one chance in 1,000 that $R > 10$).

These requirements mean that the WIPP is *not* in compliance if there is a greater than 10 percent probability of occurrence of a normalized release, accumulated over 10,000 years, that is greater than 1. In addition, DOE is not in compliance if there is a greater than 0.1 percent probability that the normalized release exceeds 10.

The above requirements are interpreted often in terms of an *exclusion region* on a graph of cumulative probability versus normalized release, as shown in Figures 6-3 and 6-4 of the CCA (Docket: A-93-02, II-G-1, Volume I, Chapter 6). In these figures, the irregular step-shaped region in the upper right corner is the region prohibited by the requirements of §191.13(a)(1) and (2). A CCDF is in compliance if the entire curve lies below and to the left of the exclusion region.

The normalized release limits in Table 1 of Appendix A to 40 CFR Part 191 are defined in terms of the amount of waste in place in the repository at the time of closure. The WIPP waste inventory estimates have been revised and updated

annually by DOE. Estimates of activity provided by the waste generators and storage sites are based on estimated activity, as stored. DOE adjusted these figures to provide estimates of all radionuclide activities decayed to the end of 1995 (see Appendix BIR of the CCA [Docket: A-93-02, II-G-1, Volumes III and IV] and CARD 24 [Docket: A-93-02, III-B-2]). To account for newly generated waste volumes, DOE assumes that the activity levels of newly generated waste will be proportional to the activity of older waste streams, on a volume basis (i.e., the curies per cubic meter will be the same).

The WIPP disposal inventory shown in Table 4-6 of the CCA (Docket: A-93-02, II-G-1, Chapter 4) is used as the basis for determining waste unit factors consistent with instructions in Table 1 of Appendix A of 40 CFR Part 191. Table 4-6 shows that 98.9 percent of the total CH-TRU curies is contributed by Pu-238, Pu-239, Pu-240, Pu-241, and Am-241. In contrast, approximately 96.5 percent of the total curies associated with RH-TRU waste is contributed by Cs-137, Sr-90, Ba-137, Pu-241, and Y-90. Almost all of the activity in the CH-TRU waste stream is from TRU nuclides, while most of the activity in the RH-TRU stream is due to fission products.

The WIPP disposal inventory data are used by the program EPAUNI (for EPA units) as the basis for determining waste unit factors. The EPAUNI program first performs calculations for determining the decay resulting in the activity levels for the year 2033, then determines the number of EPA units per unit volume, along with the associated weighting (volume factors) for each TRU waste stream. Waste unit estimates are then stored in the files EPAUNITS.OUT and EPAUNIT2.OUT for use by CCDFGF in the preprocessor mode.

The CCDFGF program combines the waste units with the estimated releases from the other PA models to calculate the cuttings, spillings and blowout releases in EPA units of measure. In Section 4.1.3.3 of the CCA, DOE states that the allowable normalized release under 40 CFR 191 is related to the number of waste units of TRU nuclides disposed of at the WIPP facility, as per the data in Table 4-6 (*ibid.*).

Methodology for Calculating the Mean CCDF

The DOE's simulations conducted with the CCDFGF code generated 100 CCDFs in each replicate. Each of the 100 CCDFs for each replicate reports the results of 10,000 futures simulated by the program. Hence, there could be as many as 10,000 steps on each CCDF curve, one step for the value of the cumulative normalized

release obtained in each of the 10,000 futures. To avoid unnecessary detail in storing the CCDFs, DOE used a binning procedure similar to that often used to create a bar chart. The range of estimated release values was divided by the DOE into 161 bins for this purpose. The CCDFGF program counts the number of futures with simulated cumulative normalized release values falling within each bin. The bin count can be zero for some bins, although most are not zero.

After the estimated release values for all 10,000 futures are binned, the CCDFGF program created a cumulative curve by calculating the number of futures with estimated releases greater than the release value associated with the upper end of each bin. The final CCDF is constructed by dividing these accumulated bin counts by the number 10,000. The specific release values estimated in any single future simulation are not retained by the model.

The 100 CCDF curves in each replicate are reduced by the DOE to a smaller number of summary CCDF curves in the program CCDFSUM. This program uses a point-wise procedure for calculating the summary curves from the original CCDFs. For example, the mean CCDF curve is generated by calculating an average of the 100 CCDF values at a selected value of the release R. The procedure is then repeated for a large number of values of R. Theoretically, this procedure could lead to as many as $100 \times 10,000 = 1,000,000$ steps on the mean CCDF curve. However, because only 161 bins were used in creating the 100 original CCDF curves, and because the bins are selected in a similar fashion for each curve, the actual number of steps on the point-wise estimated mean CCDF curve is much smaller than 1,000,000.

Similar point-wise procedures are used by the DOE to construct the 10th and 90th percentile curves. At each selected value of the release R, there are 100 CCDF values to consider. The tenth one from the top (or bottom) is used as an estimate of the 90th (or 10th) percentile summary CCDF curve at that value of R. Note that the point-wise definition may select one CCDF as the 90th percentile value at one value of R, while at the next, slightly higher value of R, a different CCDF curve may mark the 90th percentile. The mean CCDF curve for each replicate is of particular interest because the containment requirements presented in §194.34(f) are phrased in terms of the mean CCDF.

Graphs of the summary curves for the mean CCDF from each of the three replicates and the overall mean CCDF are presented by DOE in Figure 6-38 of Chapter 6 of the CCA (Docket: A-93-02, II-G-1, Volume I). The mean CCDF

curves for each replicate and the overall mean CCDF are shown by the DOE, to be in compliance by several orders of magnitude in this figure.

The overall mean and its 95 percent UCL (and 95 percent lower confidence limit) also are shown in Chapter 6 of the CCA in Figure 6-39 (*ibid.*). The 95 percent UCL for the mean is in compliance with the regulatory requirements of this section by several orders of magnitude.

Additional WIPP implementation instructions promulgated in 40 CFR Part 194 require that there be a 95 percent level of confidence that the mean CCDF is in compliance with the 40 CFR Part 191 requirements defined for a single CCDF. The DOE uses confidence intervals derived from the Student t distribution to satisfy the requirement that there be a 95 percent level of statistical confidence that the mean CCDF is in compliance. The three mean CCDF values from the three replicates are the data used for this calculation.

Let X_R denote an estimate of the mean CCDF at any value of the cumulative normalized release R , and let $SE_N(X_R)$ denote the standard error of the estimated mean due to sampling variation when the sample size is $N = 3$. The regulations at §191.13 require for compliance that the probability of exceeding a cumulative normalized release of 1 is to be less than 10^{-1} , and the probability of exceeding a release of 10 is to be less than 10^{-3} . Let L_1 denote the upper limit of probability specified in the requirement, i.e., $L_1 = 0.1$ and $L_2 = 0.001$. A 95 percent Upper Confidence Limit (UCL) is defined by DOE as:

$$UCL_R(N) = X_R + k_{.95}(N) \cdot SE_N(X_R)$$

The constant $k_{.95}(N)$ is selected using the t distribution with two degrees of freedom. The 95 percent confidence level is obtained when the UCL is below limit L_1 . X_R is the average of the three mean CCDF values, SE is the standard deviation of the three values, divided by the square of $N - 1$.

Section §194.34(f) requires that the 95 percent upper confidence limit for the mean be in compliance. Use of the CCDFGF/CCDFSUM models with $N = 10,000$ futures yields CCDFs with 100 percent of the curves lying below the limit of resolution at $R = 10$, and approximately 98 percent of the CCDFs below the limit of resolution at $R = 1$. As a result, the estimated mean CCDF is also below the limit of resolution of the model at $R=1$ and $R=10$.

Additional information on the construction and use of CCDFs to determine compliance is contained in Chapter 6 and Appendix CCDFGF of the CCA

(Docket: A-93-02, II-G-1, Volumes I and V). Chapter 6 of the CCA presents general descriptions of the risk assessment calculations performed by DOE. The chapter includes references to details provided in Appendix CCDFGF. More information on CCDF construction is provided in the *Analysis Package for the CCDF Construction* (Docket: A-93-02, II-G-10) and the *Preliminary Summary of Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant* (Docket: A-93-02, II-G-07). Discussion of the LHS procedures is included in Appendix A6 of this TSD.

a.2) A description of plausible alternative conceptual model(s) seriously considered but not used to support such application, and an explanation of the reason(s) why such model(s) was not deemed to accurately portray performance of the disposal system.

Alternative mathematical formulations that account for both stochastic and parameter uncertainty are discussed formally in Helton (1996). The analysis details several possible simulation/integration schemes for obtaining the unconditional mean CCDF. Monte Carlo integration over the stochastic variables is performed by the CCDFGF program for each LHS parameter vector. The conditional CCDFs generated by the model for each vector of parameter values are all equally likely. Hence, it is appropriate to combine them using equal weights into a single unconditional CCDF.

a.3) Documentation that:

a.3.i) Conceptual models and scenarios reasonably represent possible future states of the disposal system

The CCDFGF code simulates the occurrence of inadvertent drilling intrusions during the 10,000 years following closure of the repository. These events are assumed to occur randomly, at a rate calculated to reflect exploration drilling rates for hydrocarbons in the Delaware Basin in recent years.

The conceptual model for CCDF construction in the 1996 CCA replaces previous PA methods for modeling the Poisson process. The broad concept of a Poisson model is retained, but is implemented in a different way. The current CCA uses a simulation approach rather than the importance sampling applied in previous PAs. Multiple intrusions are simulated to occur as a random sequence of E1 or E2 events, step-by-step through 10,000 years. This approach to simulating the Poisson process is a refinement to the approximations based on importance

sampling. In previous PAs, the Poisson distribution was used to approximate the probabilities appropriate for selected multiple intrusion scenarios. In the current model, the exponential distribution is used as a model for the inter-arrival times between intrusion events.

The conceptual models in CCDFGF include sub-models in three areas:

- simulation of the Poisson process
- treatment of brine reservoirs
- the method for estimating the mean CCDF

Each of these conceptual sub-models have changed from the approaches used in previous PAs.

Poisson Model Implementation

The CCDFGF simulation is based on the Poisson process model, a probability model often used to simulate the random occurrence of discrete events within a specified time interval. The Poisson model requires only one parameter, the rate of occurrence λ . In the CCA run, DOE's use of a 600-year period for Passive Institutional Controls (PIC), following 100 years of active institutional controls (AIC), complicates the simulation model used in the CCA. During this period, which represents approximately 6 percent of the total regulatory time period, the intrusion rate is assumed by DOE to be 1/100th of the rate in the remaining 9,300 years. Because λ now changes over time, the model is called a *time-varying* Poisson process. Hence, the model consists of three different constant parameter Poisson processes, one with a rate of λ equals zero for the first 100 years, the second with a constant rate $\lambda/100$ from 100 to 700 years, and a third with constant rate λ from 700 to 10,000 years. Because the drilling rate for the 600 year PIC period set at only 1 percent of the drilling rate for the last 9,300 years, intrusions are rarely encountered until the end of the PIC period. In the EPA-mandated verification test, no credit for the PIC period was assumed (Docket: A-93-02, II-G-26).

The use of a simulation approach creates opportunities for the introduction of additional details into the modeling process that is not available in the previous formulations based on importance sampling. These additional details are implemented using a set of simulation rules that govern the simulation of multiple intrusions and brine encounters. These rules are extensions of the Multiple Intrusion and Castile and Brine Reservoirs Conceptual Models. There are different rules for each of the three release modes analyzed—cuttings, spallings, and direct

brine releases. They were implemented in a fashion to limit the estimated release due to multiple intrusions. A determination of the reasonableness of the CCDFGF simulation can be made by examination of these rules in detail.

Simulation Procedures

The ten disposal panels are considered independently in the CCA for the purpose of drilling intrusion events.

1. Starting at the time of closure ($t=0$), a random number is drawn from the exponential distribution to determine the waiting time to the next intrusion. A constant drilling intrusion rate is assumed. After the PIC period, a rate of $46.8/\text{km}^2/10,000$ years is used. During the PIC period, a rate 100 times smaller is used. (In the EPA-mandated PAVT, no credit for the PIC period is assumed.)

2. At the selected intrusion time, a second random variable is drawn to choose a location (1 of 144 discrete locations in the disposal region), and a third to determine if the intrusion is in one of the following:

- a=0 unexcavated area
- a=1 excavated RH area
- a=2 excavated CH area

3. If a=2 in the previous step, then three random numbers are drawn to select three waste streams for calculating cuttings release activity levels, drawn from the BIR probability distribution of volume across 569 waste streams. This assumes independence of the three vertically stacked drums with respect to waste streams.

4. A random number is selected to decide if the intrusion penetrates a brine reservoir. Approximately 8% of drilling intrusions hit brine, excavated or not. The calculations proceed next as follows.

a) If not excavated, the brine reservoir hit counter is incremented and determine if pressure depletion has occurred by this intrusion. The number of hits required to deplete depends on the size of the reservoir.

b) If excavated, then

1. If waste type is remotely handled (RH), do cuttings and cavings calculations only.

2. If waste type is contact handled (CH), do cuttings, cavings, spillings

and direct brine releases, as discussed below.

3. Increment brine reservoir hit count and determine if pressure depletion has occurred by this time.

5. If excavated intrusion, draw a random number to choose one of three plugging patterns:

p=1 continuous concrete plug (prob=0.02)

p=2 two plugs, one above repository, one below brine pocket (prob=0.68)

p=3 three plugs, two as above, plus one between brine and repository (prob=0.30)

Note that if plugging pattern 1 or 3 is selected, initially there is almost no bore hole flow between the brine reservoir and the repository. Plugging pattern 1 also prevents bore hole flow above the repository in the initial period. The permeability of the bore hole plugs is assumed to degrade over time, after the initial period of 200 years.

Release Calculations for Intrusions

The following procedures were developed for estimating releases using the CCDFGF code. Intrusions into the excavated area are simulated to occur at specific times $T_1, T_2, \dots, T_{n\text{BHexc}}$ during the 10,000 years after closure, where $n\text{BHexc}$ refers to the number of bore holes hitting the excavated disposal area. Each excavated area intrusion has the potential to generate four types of releases from the repository:

1. cuttings and cavings
2. spallings
3. direct brine releases
4. subsurface groundwater releases

Every excavated intrusion will generate releases due to cuttings and cavings, but the other three types only occur under specified repository conditions. The first three types of releases are surface releases expected to occur immediately (within one month) after the intrusion. Groundwater releases may continue from the time of the intrusion to the end of the 10,000- year regulatory period.

Each of the four types of releases requires a separate modeling approach in the CCA. Cuttings, cavings and spallings are estimated using the CUTTINGS_S code.

Direct brine releases are modeled within the BRAGFLO_DBR/PANEL codes. Groundwater releases, primarily through the Culebra, are modeled using the NUTS/PANEL/SECO codes. Each of these three major groups of code rely on outputs of the BRAGFLO code.

BRAGFLO provides pore pressures, brine saturations, and porosities to the CUTTINGS_S code for calculating the direct release of solids brought to the surface during and immediately after drilling. BRAGFLO_DBR receives repository properties from BRAGFLO and initial conditions from the CUTTINGS_S code. If there is sufficient pressure and brine in the repository at the time of the intrusion, this code provides estimates of the amount of radioactivity carried to the surface by brine flows immediately after the intrusion. The groundwater release codes receive complete information on subsurface brine and gas flows from the BRAGFLO code. Unlike the short time frame models used for estimating surface releases, the groundwater models require BRAGFLO outputs over the entire 10,000 year period.

The surface release models operate over a short time period and these codes are faster than BRAGFLO. However, even these codes require too much time to be able to run the codes for every excavated intrusion in each of the 10,000 futures simulated for each LHS vector of parameters. Because of this limitation, several levels of interpolation are necessary to estimate surface releases for each excavated intrusion.

The interpolation scheme proceeds as follows, for each LHS vector.

1. Using the parameter values in the vector $x_{S,U}$, the BRAGFLO model is run six times. Permeabilities assigned to each element in the bore hole are modified over the 10,000 years in six different ways, to reflect borehole conditions for six intrusion scenarios:

- S1 - Undisturbed repository conditions
- S2 - E1 at 350 years
- S3 - E1 at 1000 years
- S4 - E2 at 350 years
- S5 - E2 at 1000 years
- S6 - E2 at 800 years and E1 at 2000 years

2. Using repository conditions calculated by BRAGFLO for these six basic scenarios, the first level of interpolation is generated by running the short-term

BRAGFLO_DBR and CUTTINGS_S codes at a variety of selected intrusion times.

3. Initial excavated intrusions are modeled with the BRAGFLO_DBR and CUTTINGS_S computer codes using the S1 (undisturbed) BRAGFLO set of repository conditions as initial conditions. The computational grid used in BRAGFLO_DBR is different than the one used in BRAGFLO, with a horizontal rather than vertical orientation.
4. For multiple intrusions, only the case of two intrusions times is modeled explicitly in the BRAGFLO computer code. The second intrusion is modeled using the BRAGFLO repository conditions contained in the S2, S3, S4 and S5 scenarios. Similar passes of grid values are made as for the initial intrusions. The actual calculations are performed for a selected grid of first-intrusion and second-intrusion times shown as filled circles in Figure 4.1 in the *Design Document for CCDFGF* (Docket: A-93-02, II-G-1, Volume V, Appendix CCDFGF). At each of the 23 closed circles in the figure, the CUTTINGS_S and BRAGFLO_DBR codes were used to generate release matrices R-SP(t_1, t_2) and R-BL(t_1, t_2) where $t_2 > t_1$ and $t_1 = 350$ or 1000 years, for multiple intrusions. Similar 1-dimensional matrices also were generated for initial intrusions.
5. Interpolation and extrapolations performed by the preprocessor mode of the CCDFGF code were used to complete the calculations for the open circles in Figure 4.1. The 23 closed circle data sets provided the initial information from the BRAGFLO_DBR and CUTTINGS_S codes for these calculations. This step filled the remaining entries in the R-SP and R-BL matrices for initial intrusion times other than 350 or 1000 years.
6. At the final stage of the interpolation process, the normal mode of the CCDFGF program uses the tabulated release estimates (stored in the intermediate file RELTABRx) to estimate releases for each intrusion in the simulation of the 10,000 futures. In the CCDFGF code, the times between successive intrusions is modeled using the exponential distribution. The first draw from this distribution selects the time of the first intrusion, say t . Releases are retrieved from the RELTABRx matrix for grid times immediately before and after the intrusion time. Releases for time t are calculated using linear interpolated between the tabulated grid values. For two intrusions, say at times t and T , bilinear interpolation is required. The four tabulated values nearest the point (t, T) in Figure 4.1 (ibid.) are used for this calculation.
7. For multiple intrusions involving more than two intrusions, the releases

estimated for the second intrusion are used.

Several additional features of the simulation procedure are noteworthy:

- Intrusions that penetrate RH waste result in no spillings releases and no direct brine release. Cuttings release for RH is determined using a single RH waste stream.
- The consequence of any intrusion is calculated using linear interpolation of the appropriate input file that contains estimated scenario release values.
- A brine pocket is assigned a maximum number of hits after which it is assumed that the brine pocket will be depressurized and no subsequent hits will result in direct brine releases.
- If a brine pocket is hit for the first time and the bore hole is sealed with a plugging pattern 1, it will be as though the brine pocket was never hit, and the next hit will be treated as if it were the first.
- Hence, when the first excavated intrusion uses plugging pattern 1, subsequent excavated intrusions are treated as initial excavated intrusions for the calculation of spillings and direct brine releases until either plugging patterns 2 or 3 is used for an excavated intrusion.

Assumptions for Groundwater Releases

Although previous PAs addressed groundwater releases through the Culebra as the main component of release to the accessible environment, the current CCA analysis for groundwater releases from the repository into the Culebra indicates that releases do not reach the accessible environment due to physical and chemical retardation effects in the Culebra. Because there are no releases to the accessible environment to model, an alternative approach was developed for the CCA which models releases *into* the Culebra as a result of E1 and E2 type intrusions.

Releases *into* the Culebra that remain within the WIPP land withdrawal area are not a directly regulated quantity and calculations done for this pathway are more for the purpose of understanding the modeling process than for compliance demonstration. These calculations were not presented in the CCA delivered to EPA. Some results of this modeling of movement within the Culebra are discussed in the report entitled *Preliminary Summary of Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant (A-93-02, II-G-7)* provided circulated after the

CCA was delivered to EPA.

Additional modeling assumptions are required to estimate the cumulative groundwater release into the Culebra of element k of decay chain j due to an intrusion of type E1, E2 or E1E2 at time t into waste panel p . The assumptions are detailed in the four unnumbered equations appearing at the end of Table 4.8 in Section 4.5 of the CCDFGF Design Document (A-93-02, II-G-1, Volume V). The equations describe the CCDFGF procedure for using interpolated results from a relatively small number of BRAGFLO/PANEL/NUTS model calculations to assign appropriate cumulative releases to the simulated E1, E2 and E1E2 event sequences encountered in the simulation.

The interpolated BRAGFLO/PANEL/NUTS release information is contained in the terms $rE1(I, j, k, l)$, $rE2(I, j, k, l)$ and $rE12(I, j, k, l)$ which are defined as the cumulative groundwater release from the repository into the Culebra of element k of decay chain j from time I to time l due to an E1, E2 or E1E2 type intrusion, respectively. Colloidal movements are tracked by species within the model. The fraction of radionuclide k of decay chain j that is attached to colloidal species s is contained in the terms $fCE1(s, j, k)$ and $fCE2(s, j, k)$ for the E1 and E2 scenarios, respectively. Of the four equations in Table 4.8, the first two treat releases for the dissolved radionuclides that are not attached to any colloidal species, while the final two equations treat releases of radionuclides attached to colloidal species. In each set of equations, the first equation defines releases on a panel-by-panel basis, while the second equation sums the results over all panels. Hence the first equation in each set is the most detailed equation for examining the assumptions concerning multiple releases.

The first equation in each set contains four different expressions, for four different time periods. The first time period covers the period up to the first excavated intrusion ($t < p_1$). In this time period, the repository is in the undisturbed condition and releases to the Culebra are set equal to zero.

The second time period covers the time from the first intrusion in an excavated area of panel p to the second excavated intrusion in the same panel. If the first excavated intrusion is an E1 event, the groundwater release into the Culebra from this panel in the second time period is assigned using the BRAGFLO/PANEL/NUTS E1 release results. If the next excavated intrusion is an E2 event, then the first E1E2 event arises, which is covered by the fourth expression.

If the first excavated intrusion is an E2 event, the groundwater release into the Culebra in the second time period is assigned using the BRAGFLO/PANEL/NUTS E2 release results. This level of consequence is maintained until an E1 event occurs. Then the first E1E2 event arises, which is covered by the fourth expression.

In the fourth expression of the first equation of each set the consequences of multiple E1E2 intrusions are calculated for all time periods after the occurrence of the first E1E2 event. From the time of the first E1E2 event, multiple E1E2 groundwater releases are assumed to remain that of a single E1E2 event, until the next E1 event. That is, any additional E2 events will not cause greater releases because, it is argued, the single bore hole into the brine pocket is the limiting factor. Subsequent E1E2 events are defined to occur when the subsequent E1 events occur—after the first E1E2 event—regardless of the number of E2 events that occur in the intervening period. As additional E1 events are encountered, the release profiles from additional E1E2 events are added to the release profiles of the earlier E1E2 events.

Brine Pocket Conceptual Model

The probability of a drilling intrusion encountering pressurized brine is treated as a constant parameter in the CCA. This parameter determines the relative proportion of drilling intrusions into the repository that are expected also to strike pressurized brine in the Castile formation beneath the WIPP. The parameter is used in the CCDFGF code to determine the probability of an intrusion hitting pressurized brine. The percentage underlain with brine reduces both the frequency and consequences of the E1E2 scenario. Intrusions that strike brine result in higher releases to the accessible environment due to direct brine release, increased likelihood of releases due to spallings, and an increase in the chances of groundwater releases into the Culebra formation above the repository.

The CCA documentation for this parameter shows that a constant probability value of 0.080 was used in the CCA for this parameter. Supporting documentation for this value is presented in the MASS Attachment 18-6 (Docket: A-93-02, II-G-1, Volume X, Appendix MASS) where a probability of 0.082 is recommended based on semi-variograms and ordinary Kriging analysis of drill hole data.

The geostatistical analysis correlates occurrence of brine reservoirs with disturbed areas of the Castile, using driller-reported brine encounters in a broad area of the Castile surrounding the WIPP site. The estimated spatial correlation distance for

the brine-encounter data is smaller than the distance from the disposal site to WIPP-12. Hence, in the absence of other data within a few correlation distances of the WIPP site, the analysis assigns a probability value at the WIPP site that is near the wide-area average for undisturbed regions of the basin. This value is 8 percent.

The geostatistical approach ignores the local depth-to-first-conductor data obtained in the TDEM study (Docket: A-93-02, II-G-1, Ref. #229) reported in the 1992 WIPP PA. Given the large uncertainty surrounding the existence of brine in the vicinity of the disposal site, there appears to be little justification for the use of a single fixed percentage for this parameter. However, the Conceptual Models Peer Review Panel considered the impact of a change in the percentage of brine encounters on the overall CCA results to be small (Docket: A-93-02, II-G-12, p.2).

Other assumptions effect brine pockets in the model. A new feature of the conceptual model introduced for the CCA is the assumption that the Castile brine reservoir will experience pressure depletion due to bore holes drilled through both the excavated and unexcavated areas inside the berm. The index for selecting a brine pocket is an LHS parameter used in the CCDFGF code (Docket: A-93-02, II-G-1, Volume XI, Appendix PAR, p. PAR-113). This parameter determines the size of brine pocket that may be encountered in the Castile formation beneath the WIPP. The size of the brine pocket and the initial pressure in the brine pocket are used in the BRAGFLO code to determine the potential for brine flow into the repository after penetration by drilling intrusions.

The documentation for this parameter (*ibid.*) describes a discrete probability distribution with 32 equally likely integer values ranging from 1 to 32. These values are mapped to one of five possible brine pocket volume values: 32,000, 64,000, 96,000, 128,000 or 160,000 cubic meters. The assigned distribution is skewed toward the low end of the size range. A total of 19 of the 32 possible integer values for this variable are assigned to the smallest size brine pocket, 32,000 cubic meters. Ten integers each are assigned to the 64,000 and 96,000 cubic meters size classes. Five integers are assigned to the 128,000 cubic meter size class, and one integer to the largest 160,000 cubic meters size category. The result is that less than 20 percent of brine pocket encounters involve the two largest size classes: 128,000 or 160,000 cubic meters, with over 80 percent of encounters being of size 96,000 cubic meters or less. (See Technical Support Document for Section 194.23: Parameter Justification Report, Docket: A-93-02, III-B-14 for additional discussion.)

a.3.ii) [mathematical models incorporate equations and boundary conditions which](#)

reasonably represent the mathematical formulation of the conceptual models.

DOE uses a simulation approach to generate estimates of the CCDF curve for WIPP performance assessment. The conceptual model for the simulations is based on the Poisson space-time process, a probability model used to simulate the random occurrence of discrete events at a given rate within a specified time interval, geographical area, or both. The Poisson space-time model for intrusions into the WIPP disposal area requires only one parameter, λ , the average rate of intrusions per km² per 10,000 years.

The CCDFGF code is designed to calculate one CCDF for each LHS vector of sampled parameters. The program estimates probabilities for the scenario consequences obtained from the other models to generate a CCDF for each LHS vector of parameters. The CCDFGF code reads the files created by the other PA models for each scenario and performs stochastic simulations necessary to generate 10,000 futures.

The cumulative normalized release for each future is retained, and used to construct a CCDF of release values. The value of CCDF(R) is calculated for any R by counting the number of futures that result in cumulative normalized release greater than R, then dividing the count by the total of 10,000 futures. Using this estimator, the smallest probability value that can be simulated by the model is $1/10000 = 10^{-4}$, which may be considered as the lower limit of resolution of the model when used to estimate probabilities based on the Poisson space-time model. This approach is consistent with the EPA requirements in §194.32(d) that performance assessments need not consider processes and events with an occurrence probability less than 10^{-4} .

The specific equations used to estimate releases within each future are designed to reflect the Poisson space-time conceptual and mathematical models. The program first uses random sampling from the exponential distribution to simulate the inter-arrival times between intrusion events in the temporal part of the Poisson process. Additional random variables are introduced to simulate whether the intrusion hits an excavated area or not, the type of bore hole plugging pattern used, whether brine is hit or not, which panel is hit, which waste containers, etc. With the exception of plugging pattern and waste container, these variables are assumed to be distributed randomly over the disposal area proportional to the areas involved, as expected for the spatial portion of the Poisson process.

Plugging patterns are implemented with a non-uniform distribution, in accordance

with historical experience. Waste containers are simulated from a list of 567 waste streams in proportion to their expected frequency in filling the repository, based on DOE's waste inventory data (Docket: A-93-02, II-G-1, Volumes III-IV). These two variables are not part of the Poisson space-time conceptual model, but reflect the historical record and future expectations.

There are no boundary conditions used in these calculations, which depend on Monte Carlo simulation methods rather than direct numerical algorithms which would lead to analytic solutions of the relevant physical equations.

a.3.iii) numerical models provide numerical schemes which enable the mathematical models to obtain stable solutions.

The Monte Carlo simulation approach is used in the CCDFGF code to implement numerical evaluation of the mathematical models. The Monte Carlo method simulates the occurrence and location of intrusions into the repository over 10,000 years. The numerical quantity estimated in the simulation is the proportion of simulated futures with a cumulative normalized release greater than R —this is a calculation used to estimate the CCDF at R .

The stability of the simulation method for estimating the CCDF is determined by the number of futures used in the simulation. In the current CCA, 10,000 futures are simulated. The sample size limits the numerical accuracy for the estimation of probabilities to within approximately $\pm 10^{-4}$ at all levels of probability reported by the code. The probabilities of interest in evaluating compliance are 10^{-1} at $R = 1$ and 10^{-3} at $R = 10$, where R is the cumulative normalized release. Hence, the approximate percentage error contributed by the use of 10,000 futures ranges from 1 percent to 10 percent, respectively.

The CCDFGF computer code also requires numerical algorithms for random number generation and for interpolation. The random number generator algorithm and code was selected by Press 1992 as the "best" uniform random number generator, in this standard source of off-the-shelf FORTRAN code. The interpolation routines use both linear and bilinear interpolation. Interpolation results in a small amount of additional error in the estimated release values. The magnitude of this error is small with respect to the larger sources of uncertainty in the release estimates, including model specification, homogeneity and parameter uncertainty.

a.3.iv) computer models accurately implement the numerical models; i.e.,

computer codes are free of coding errors and produce stable solutions.

The *Implementation Document* for the CCDFGF program contains approximately 15,000 lines of FORTRAN, encompassing approximately 140 subroutines and user-defined functions. The test plan presented in the VVP provides functional requirements related to the correct coding implementation of the CCDFGF numerical model. For dynamic analyses, the Validation Document (VD) describes four tests to validate the CCDFGF code. The first test is a test of the preprocessor mode, while tests 2, 3, and 4 are for the normal mode of operation of the CCDFGF code. A complete replication of the tests was conducted by EPA within the EPA-CMS framework to verify proper code implementation for the CCA.

In addition, the CCDFGF program prints a diagnostic to report results of internal tests that are designed to ensure the probabilities of events generated by the model match closely with calculated probabilities from the assigned probability distributions. These distributions closely match the theoretical distributions.

The program CCDFGF estimates releases of radionuclides by multiplication of an activity level times the estimated volume of material releases. For fixed activity, the resulting release should be linearly proportional to the volume released. Alternatively, for fixed volumes, the estimated releases should be linearly proportional to the activity of the material. This property of the CCDFGF code is referred to as bilinearity, which was the subject of an additional test conducted by EPA. Examination of the outputs for this comparison showed that this part of the bilinearity test was successfully completed and produced adequate results for use in the CCA PA.

EPA's analysis concluded that the DOE has presented performance assessment results in CCDFs which show the probability of exceeding regulatory levels of cumulative releases. Numerical models for the calculation of the WIPP CCDFs are defined in Appendix CCDFGF, also known as the *Design Document for CCDFGF*. The CCDFGF Fortran code for implementing the numerical model is presented in the *Implementation Document*. The correctness of the implementation is demonstrated using tests proposed in the *Verification and Validation Plan*. The results of the validation tests obtained by DOE are presented in the *Validation Document*. EPA review of the validation tests for the CCDFGF code is discussed in Section b.1(6). Additional tests performed on the code by EPA are discussed in Section b.2(7) of this Appendix.

a.3.v) conceptual models have undergone peer review according to § 194.27.

As discussed in Chapter 9 of the CCA (Docket: A-93-02, II-G-1, Volume I), the conceptual models contained in CCDFGF modules have undergone Peer Review. The Conceptual Models Peer Review Panel reviewed the exclusion of large brine reservoirs, and the depletion of reservoir pressure due to repeated intrusions. The Panel agreed with these approaches.

The Peer Review Panel assessed the use of a single-event model such as BRAGFLO to evaluate releases for multiple intrusions in the E1E2 scenario and found this to be an adequate approach.

The Peer Review Panel stated two specific objections to the approach presented by Powers, *et. al.* (Docket: A-93-02, II-G-1, Volume X, Appendix MASS, MASS Attachment 18-6), for estimating the probability of encountering brine. These were:

- (1) the lack of data in the immediate vicinity of the WIPP
- (2) the implicit assumption that geologic conditions at the WIPP would be similar to those in areas where brine encounters and drilling are more abundant

The Panel also noted that the time-domain electromagnetic geophysical study completed by the DOE prior to the current geostatistical study represents the only site specific data over the waste panel area, and very significant low resistivity anomalies were noted under some of the waste panel area that are consistent with the depths of the lower to middle Castile. The Peer Review Panel questioned the geostatistical approach (independent of geophysical data) for modeling the probability of intercepting a brine reservoir when more specific indicators and site specific data are available. However, the Panel also noted that it expected these shortcomings would have only a small impact on the overall results of the assessment.

b) Computer codes used to support any compliance application shall be documented in a manner that complies with the requirements of ASME NQA-2a-1990 addenda, part 2.7, to ASME NQA-2-1989 edition. (Incorporation by reference as specified in §194.5)

The CCDFGF program may be run in two modes. In the first mode, called the preprocessor mode, the program collects required outputs for 100 LHS vectors from the other PA programs and writes these results to an intermediate file RELTABRx, where x denotes the replicate number. The file contains an array of

consequence estimates, written here as $R_{s,c,e,t,h}$, and the associated times t for each consequence value. The R matrix contains consequence and time values for each:

- LHS observation, $s = 1, \dots, 100$
- category of release, $c = \{\text{CUSP, BF4, NUTS, SECO}\}$
- type of intrusion scenario, $e = \{\text{E0, E1, E2}\}$
- time of intrusion, $t = t_1, \dots, t_n$
- upper or lower panel, $h = \text{U/L}$

When run in the normal mode, the CCDFGF program reads this intermediate file, and performs stochastic simulations necessary to generate $N = 10,000$ futures for each LHS input vector. Within each future, the program samples to determine the time to the next intrusion, whether the intrusion hits an excavated area or not, the type of plugging pattern used, whether brine is hit or not, which panel is hit, which waste containers, etc. While simulating each future, the program keeps track of multiple intrusions into the waste panels and into the brine pocket to implement specific rules for the treatment of multiple intrusions.

In simple terms, the normal mode of the program attaches probabilities to the consequence estimates contained in RELTABRx to generate a CCDF for each LHS vector. The result is a set of 100 CCDFs for each of the three replicates. The data set for the CCDF curves, consisting of a set of graph points, $\{R, F_{s,c}(R)\}$ contains separate estimates for each category of release c , as well as CCDFs which are combined over all categories of release ($c=0$). The values $F_{s,c}(R)$ are generated by counting how many of the 10,000 futures result in cumulative release over greater than R , then dividing that count by 10,000. Using this estimator, the smallest probability value that can be simulated by the model is $1/10000 = 0.0001 = 10^{-4}$.

- *Technical evaluation of adequacy of CCA PA QA documents*

QA documents specific to the CCDFGF code are discussed in this section (See Docket: A-93-02, II-G-3, Volumes 2 and 3).

- *Requirements Document/Verification and Validation Plan*

Functional requirements are listed in the *Requirements Document*. The test plan presented in the VVP fully develop for the functional requirements. This provides additional functional requirements related to the correct implementation of the CCDFGF code. Additional tests are presented to ensure that the preprocessor

mode of the program correctly interpolates and extrapolates the release tables received from other PA models. Seven tests are presented for the simulation rules discussed in Section a.3.i of this Appendix. Additional internal consistency checks are part of the CCDFGF code to ensure that the probabilities of events generated by the model match closely with calculated probabilities from the assigned probability distributions.

The acceptance criteria listed in the VVP rely on visual inspection of printed outputs and comparison to printed inputs. Verification using hand calculations is also proposed.

- *Implementation Document*

The *Implementation Document* for the CCDFGF program contains approximately 15,000 lines of FORTRAN, encompassing approximately 140 subroutines and user-defined functions. This code was used to compile the executable, CCDFGF_PA96.EXE, used for the CCA.

- *User's Manual*

The User's Manual provides instructions for running the codes and describes capabilities and limitation. Hardware and software requirements are cited.

- *Validation Document*

The Validation Document first reports the results of static analyses on the CCDFGF code, including a FLINT analysis and coverage analysis. The static analyses were done using the DEC-supplied source code analyzers. The FLINT analysis reported several variables that were set but later were not referenced. These were determined to be features of the code which are not used in the CCA PA. The FLINT analysis also reported lines in excess of 72 characters. These were determined to be caused by extra blanks at the end of records which have no effect in the code.

The coverage analysis reported that seven subroutines were not functional in the code: E1E2R, E1ORE2, EPAREL, NOBH, PRTTST, RELCUT, and RELMDS. These were not used in the CCA analysis. Additional analyses of the CCDFGF PA96 code revealed that there are five other subroutines which are referenced and called, but have been "short-circuited" by placing a Return statement as the first executable statement in the subroutine. See section d.2(8) of this Appendix for a list of these subroutines.

For dynamic analyses, the VD describes four tests to validate the CCDFGF code. The first test is a test of the preprocessor mode, while tests 2, 3, and 4 are for the normal mode of the CCDFGF code. A complete replication of Tests 1, 2, 3 and 4 was conducted by EPA to verify these tests. The latter three tests run the CCDFGF executable in the normal mode, using command script files (*.COM) to define the working directory, source for executables, and necessary input files. Output files are written on the same directory with the inputs. The script was modified as needed to run the three tests.

The original script for Test 3 was prepared by Mike Williamson of DEC, who also set up a Configuration Management System, the EPA-CMS, to record file operations for QA purposes as the tests are reproduced. The EPA-CMS contains pointers to the original CCA-CMS. It will also contain new files created by EPA, and records all file operations. The commands *CSE CMS show element*, and *CFE CMS fetch element*, are available to find and fetch elements (files) from the EPA-CMS libraries. To locate the files needed for the CCDFGF code, the command LIBCCGF was used to direct the current pointer to the CCGF library, prior to using the CSE and CFE commands.

Only one input file differs among the latter three tests. This file is named to facilitate use of a unique CMS search identifier, such as "CSE *MISC*.INP" to locate the file in the CMS. The necessary MISC input file for each test was located in the EPA-CMS using the CSE command and fetched to the current working directory using the CFE command. The remaining input files to each of the three tests are identical. These files were retrieved from the EPA-CMS on Wednesday, January 15, 1997, by Mike Williamson, to the [.MIKE_FILES] subdirectory on the [ROOT.ABWOLBA] directory.

Chronologically, The tests were reconstructed in this order: Test 3, Test 4, Test 2, then Test 1.

Reconstruction of Test 3

The following steps were completed to review Test 3:

Created working directory [.T3] and moved to that directory.

Copied all input files from the MIKE_FILES subdirectory. Also copied .COM script from that directory. Used CFE to fetch *MISC*.INP files from the CMS to the T3 directory. Modified the .COM script to access the current working directory. At this point the .COM script referred to the executable named

“PA96_2,” as indicated in the script received from Mike Williamson.

Compared the output file CCGF_CCDFGF_T3.OUT with the corresponding file fetched from the CCA-CMS using the VAX DIF command. The files did not match. The code's author, Jay Johnson of Gram, Inc., informed us that the PA96_2 executable is the latest version 1.01, which has been modified since the CCA was prepared. After modifying the .COM script to access the older executable named “PA96,” the script was run again. This time the output files matched exactly with the output files obtained from the CCA-CMS, because PA96 is the version 1.00 executable used in the tests EPA received from SANDIA.

Reconstruction of Test 4

Created working directory [.T4]. Used CFE to fetch the *MISC*.INP file for Test 4. Modified .COM script from Test 3 to run Test 4. Copied all necessary input files, other than the MISC file, to the working directory from the [.T3] directory. Ran both the Version 1.00 and Version 1.01 tests. Used DIF to compare the 2 sets of output files to the corresponding files in the EPA-CMS. All four output files matched exactly.

Test 3 and 4 Summary

Test 4 is somewhat different than Test 2 and 3. The Tests 2 and 3 provide printouts of selected observations and futures from the PA run performed for the CCA. Test 4, however, uses modified parameter values for the maximum number of intrusions which can produce spillings or blowouts, to test these features of the code. These features could not be tested using the actual CCA parameters because the assigned maximum values are never reached in the CCA simulation.

Reconstruction of Test 2

Created directory [.T2]. Copied script from Test 4 and input files (other than *MISC*.INP) from the Test 3 directory. Used CFE to fetch the *MISC*.INP file for Test 2 from the CCA-CMS.

Modified the .COM script to address the current working directory and to access the PA96 (Version 1.00) executable for the test.

Ran the script to generate the output files for Test 2. Could not find an output file CCGF_T2.OUT in the CCA-CMS for comparison. Found larger output file, CCGF_CCDFGF_T2.OUT, which contains detailed futures listings to complete the visual comparison part of Test 2.

Matched the CCGF_CCDFGF_T2.OUT file from the test run to the corresponding file in the CCA-CMS using DIF. No differences were found.

In addition to the test files, input files and executables for Version 1.00, the EPA-CMS has corresponding files for the newer Version 1.01 of the PA, usually referred to with the symbol _2, e.g., PA96_2. While conducting the tests of Version 1.00, the tests were also successfully run on Version 1.01. To the extent which these tests were completed, the new version test output files all matched with those generated by Sandia during the recently completed test runs on the new Version 1.01 executable.

The data file RELTABR1 used in Tests 2, 3, and 4 is produced by the preprocessor mode of CCGF. This file contains all release values from the other modules of the PA. Tests 2, 3, and 4—which test the normal mode of the CCGF code—read this file as a primary input file. However, the file was also created by the CCGF executable, when run in the preprocessor mode.

Reconstruction of Test 1

Test 1 involves running EPAUNI, LHS, in both the preprocessor and normal modes of the CCDFGF program, and the final summary program CCDFSUM. Considering the strong performance of the normal mode of the program in Tests 2, 3 and 4 discussed above, the most crucial aspect is that Test 1 addresses the correct operation of the preprocessor mode of the CCDFGF program. Running the preprocessor mode requires over 150 input files, many of are not easily located in the CMS. Test 1 also differs from Tests 2, 3 and 4 in that the results for all three replicates are required to test the program CCDFSUM. All programs up to and including CCDFGF_1 must be run for all three replicates before running the CCDFSUM program. Due to the complexity of Test 1, with the large number of input files and long job submission times, the test was not reconstructed in a single run. A detailed execution script (EVAL_CCGF_OCT96.INP) was prepared to define all job steps and the required CMS input files. This re-entrant script, prepared by Mike Williamson and Kathy Aragon of Digital Equipment Corporation, under contract with SNL, permitted running selected subsections of the job stream in different phases. A listing of the entire script is provided at the end of this appendix.

Using the evaluation script, the reconstruction of Test 1 was conducted in three phases:

- 1) Preprocessor mode of CCDFGF - 3 runs, 1 for each replicate

- 2) Normal mode of CCDFGF - 3 runs, 1 for each replicate
- 3) CCDFSUM - 1 run, uses all 3 replicates

The input files required for running Test 1 are listed at the end of this appendix. These files were used as proxies for the real data in the development of the program. Although the input files are still required to run the program, much of the proxy data contained in these input files is ignored, being over-written later in the CCDFGF program by values obtained from the most recent CCA-CMS run. The input files are:

- CCGF_MISC_POSTCCA_VERBOSE_1.INP
- CCGF_NODE3_CCA.INP
- CCGF_INV5_CCA.INP
- CCGF_REGION_CCA.INP

Phase 1

After the necessary input files were assembled on a local working directory, the three phases of the Test 1 verification were conducted using scripts that accessed files from the EPA-CMS files associated with the OCT_96 class. The entire script is included in the files listed at the end of this appendix, under the name EVAL_CCGF_OCT96.INP. A portion of the beginning of the script used for phase 1 is listed here:

* The codes/steps that are accessible from this script are:

```
*      EPAUNI_RH
*      EPAUNI_CH
*      PRECCDFGF
*      PRELHS
*      LHS
*      CCDFGF_1
*      CCDFSUM_PLT_1
*      CCDFSUM_ADOBE_1
*
```

```
* WARNING - run up through CCDFGF_2 for R1, R2, and R3 before
* running the CCDFSUM steps. CCDFSUM expects output files from
* all 3 replicates and will fail without them.
*
```

```
*-----
* GLOBAL SYMBOLS AND LOGICALS
SYMBOL          UNIQUE_ID          OCT96
SYMBOL          USER_TYPE          EPA
SYMBOL          INPUT_CLASS      oct96
SYMBOL          REPLICATE_NUM          1
SYMBOL          FIRST_CODE          EPAUNI_RH
SYMBOL          LAST_CODE          PRECCDFGF
LOGICAL          WORKING_DIR          sys$login
*
```

Using the FIRST_CODE, LAST_CODE and REPLICATE_NUM features, the

script was executed in phase 1 from the program EPAUNI_RH to the program PRECCDFGF for each replicate by changing the value assigned to REPLICATE_NUM from 1 to 2 to 3. During this phase the script reads a large number of files containing consequence estimates for cuttings, spillings and direct brine releases for each scenario. The results are written to the intermediate file RELTABRx for each replicate $x = 1, 2, 3$.

After completing the phase 1 runs for each of the three replicates from the PRELHS program to the CCDFGF_1 program, the output file RELTABRx was checked against the corresponding RELTABRx files included in the CCA-CMS using the Difference program. Outputs of the difference program runs are included at the end of the appendix. No difference were noted in the comparisons.

Phase 2

After examining the phase 1 output files for each replicate, the second phase of the EVAL_ script, from the program PRELHS down to and including the program CCDFGF_1, was executed by modifying the FIRST_CODE and LAST_CODE features:

```
SYMBOL    FIRST_CODE    PRELHS
SYMBOL    LAST_CODE     CCDFGF_1.
```

In this phase, the script was executed from the program PRELHS to the program CCDFGF_1 for each replicate by changing the value assigned to REPLICATE_NUM. This phase of the reconstruction of Test 1 creates output files with CCDFs that describe results the simulations performed by the normal mode of the CCDFGF code for each replicate. In the CMS, the phase 2 output file for replicate 1 is named CCGF_POSTCCA_R1_VERBOSE_1.OUT. The reconstructed output file for replicate 1 in phase 2 has the name CCGF_R1_1_OCT96.OUT. Similar files were prepared for replicates 2 and 3. After completing the phase 2 runs, the output files were compared to the corresponding output files included in the CCA-CMS. No difference were encountered when the Difference program was used to compare the two files. Output files showing the results printed by the Difference program are listed at the end of this appendix.

Phase 3

Phase 3 includes the final section of the script, which runs the program CCDFSUM. As noted in the warning in the portion of the evaluation script listed

above, this phase is run after all three replicates have successfully completed using the preprocessor and normal modes of the CCDFGF program in phases 1 and 2. The CCDFSUM program creates the summary mean CCDF curves for each replicate, estimates of the overall mean and its confidence interval, and graphs of all CCDFs in Postscript and Adobe formats.

The FIRST_CODE and LAST_CODE lines of the EVAL script are modified for this phase as follows:

```
SYMBOL    FIRST_CODE    CCDFSUM_PLT_1
SYMBOL    LAST_CODE     CCDFSUM_ADOBE_1.
```

After completing the phase 3 run, the output file CCGF_CCDFSUM_1A_OCT96.OUT was compared to the corresponding output file CCGF_CCDFSUM_POSTCCA_VERBOSE_1A.PLT included in the CCA-CMS. No differences were found when the difference program (DIF) was run on the two files. The output of the difference program is listed at the end of this appendix.

A bilinearity test was also conducted by EPA of the CCDFGF code. The program CCDFGF estimates releases of radionuclides by multiplication of an activity level times the estimated volume of material releases. For fixed activity, the resulting release should be linearly proportional to the volume released. Alternatively, for fixed volumes, the estimated releases should be linearly proportional to the activity of the material. This property of the CCDFGF code is referred to as bilinearity, which is the subject of an additional test conducted by EPA.

The bilinearity test was designed to determine if the CCDFs generated by the CCDFGF program respond linearly to its two inputs, volume and activity. The base run for the model in normal mode uses a selected LHS vector to generate an intermediate release matrix R for that vector. This matrix generates a set of CCDF graph points F. The test was conducted by increasing ten-fold all release volumes contained in the RELTABR1.DAT data file that is generated by the preprocessor mode of the CCDFGF program. The version of this file used as the Replicate 1 input for Test 2 was selected as the basis for this test.

The release volumes in each sub-matrix of the intermediate release tables were multiplied by a factor of 10. The program for doing this multiplication was constructed by deleting all unnecessary code from the current CCDFGF FORTRAN code, other than the subroutines required to read and write the intermediate release file. The program, named RELT.FOR, is listed at the end of

this appendix. The CCA-CMS contains the output file CCGF_T2_PA96.OUT from the CCDFGF normal mode when the data file RELTABR1.DAT is used as the input file for Test 2. The adjusted RELTABR1.NEW matrix created by the program RELT.FOR was then used as input to a second run of the normal mode of the CCDFGF program, generating a second version of the CCDFGF output file with the same name, but stored on a different directory.

A second FORTRAN program, named CCG.FOR, was used to read the output file associated with the adjusted RELTABR1.NEW input file, and divide all estimated release values by the same factor of 10 used to adjust the RELTABR1.NEW file. The CCG.FOR program is listed at the end of this appendix. The output file from CCG.FOR was named CCGF_T2_PA96.NEW. The two versions of the output file from CCDFGF were then compared using the Difference program. No differences were found. Output of the difference program is listed at the end of this appendix (see Attachment 1).

A similar program was used to multiply all radioactivity concentrations received from EPAUNI by a factor of 10, generating a second test output. It was expected in each case that the new sets of CCDF curves would be higher by a factor of 10 at all values of the cumulative normalized release. Examination of the outputs for this comparison showed that this part of the bilinearity test was successfully completed also.

EPA's analysis concluded that the DOE adequately tested the functional requirements of the CCDFGF computer code and that the additional test done by the Agency shows that the computer code is adequate for use in the CCA PA.

c) Documentation of all models and computer codes are included as part of any compliance application performance assessment calculation shall be provided. Such documentation shall include, but not be limited to:

c.1) Descriptions of the theoretical backgrounds of each model and the method of analysis or assessment,

The theoretical background of the CCDFGF code is discussed in Chapter 6 of the CCA (*op. cit.*) and in Appendix CCDFGF (*op. cit.*). Complete mathematical details of the approach are presented in Helton 1996.

c.2) General descriptions of the models; discussions of the limits of applicability of each model; detailed instructions for executing the computer codes, including hardware and software requirements, input and output

formats with explanations of each input and output variable and parameter (e.g., parameter name and units); listings of input and output files from a sample computer run; and reports on code verification, benchmarking, validation, and quality assurance procedures.

- *Limits of applicability*

The User's Manual (p.8) notes that the software can only be used if input file from the CCA PA calculations are first condensed for use by CCDF using the SUMMARIZE software.

- *Detailed instructions for executing code*

The User's Manual is inadequate for running the code. Instructions for running the code contained in the VVD test discussions are more informative.

- *Hardware requirements*

Hardware requirements are specifically addressed in the *User's Manual*.

- *Software requirements*

Section 6 of the User's Manual summarizes software requirements.

- *Input and output formats*

Input and output formats are discussed in the *User's Manual* (pp. 10-12). Sample pages are printed in the Appendices to the User's Manual.

- *Explanation of each input and output variable and parameter*

Mathematical definitions of each input and output variables are provided in Appendix CCDFGF, (pp. 14 - 52). Additional information is included in Chapter 6 and Appendix MASS.

- *Listing of input and output files*

Listings of the input and output files are included in the *User's Manual* and in the *Validation Document*.

- *Explanation of each parameter with name and units*

The mathematical definitions of each variable and the appropriate units are presented in Appendix CCDFGF, pp. 14 - 52.

- *Report on code verification*

See *Report on Code Validation* below.

- *Report on benchmarking of code*

No report on benchmarking of the new CCDFGF code was located. There is no prior standard to support a benchmarking.

- *Report on code validation*

The VD reports the results of four tests performed to validate the CCDFGF code. The acceptance criteria rely on visual inspection of printed outputs and comparison to printed inputs. Verification was also done using hand calculations. Results of the tests of the preprocessor and normal modes indicate all requirements listed in the VVP were satisfied.

- *Report on quality assurance procedures*

Reviewer forms for the *Requirements Document*, the *Verification and Validation Plan*, the *User's Manual*, *Implementation Document* and *Validation Document*, with cover sheets was received.

c.3) Detailed descriptions of the structure of computer codes and complete listings of the source codes.

- *Detailed description of the structure of the computer code*

The *Validation Document* provides a listing of the call tree for the code on pp. 33 - 35.

- *Detailed listing of the computer code*

The *Implementation Document* for the CCGF program contains a listing of approximately 15,000 lines of FORTRAN, encompassing approximately 140 subroutines and user-defined functions. Build scripts are also included.

c.4) Detailed descriptions of data collection procedures, sources of data, data reduction and analysis, and code input parameter development.

- *Description of data collection procedures*

The random numbers generated in the CCDFGF program to simulate future drilling scenarios require parameters for each type of variable. The model includes

the following variables.

1. Drilling rate parameter to be used in the exponential distribution for the waiting time to next intrusion. A constant drilling intrusion rate is assumed. The CCA uses a period 600 years in which passive institutional controls are assumed to be effective. After the PIC period, a rate of 46.8/km²/10,000 years is used. During PIC period, a rate 100 times smaller is used. No intrusions are assumed to occur during the initial 100 years when active institutional controls are assumed to be effective.
 2. A discrete random variable to choose a location as one of 144 discrete locations in the disposal region. This distribution assigned is discrete uniform.
 3. A variable for non-excavated, excavated CH, or excavated RH intrusions.
 4. Three random numbers drawn to select three waste drums for calculating cuttings release activity levels. The probability distribution for this variable comes from the BIR distribution of volumes across 569 selected waste streams. The waste stream data are discussed in Appendix BIR (Docket: A-93-02, II-G-1, Volumes III-IV).
 5. A random number to decide if the intrusion has penetrated a brine reservoir. Approximately 8 percent of drilling intrusions hit brine, excavated or not.
 6. A random number to choose a plugging pattern:
 - p=1 continuous concrete plug (prob=0.02)
 - p=2 two plugs, one above repository, one below brine pocket (prob=0.68)
 - p=3 three plugs, two as above, plus one between brine and repository (prob=0.30)
- *Identification of sources of data*

The model includes the following variables and the corresponding data sources.

1. Exponential distribution rate parameter. A fixed drilling rate is used based on the use of Delaware basin drilling data, as required by §194.33(b)(3). The use of a factor of 100 for the PIC period is entirely subjective. This assumption was not used in the EPA-mandated PAVT (Docket: A-93-02, II-G-26).

2. Location in the disposal region. This distribution is assigned as discrete uniform to make all locations equally probable.
 3. Variable for non-excavated, excavated CH, or excavated RH intrusions. This distribution is determined from the geometry of the site.
 4. Waste stream distribution. The BIR data underlying this distribution are discussed in CARD 24 (Docket: A-93-02, II-B-3).
 5. Percentage of disposal area underlain by pressurized Castile brine. Supporting documentation for this fixed parameter is discussed below in the description of data reduction and analysis.
 6. Index for selecting a brine pocket. This LHS parameter is discussed below under input parameter development.
 7. Random number for plugging pattern. The probabilities are assigned based on a field survey as discussed in Appendix DEL of the CCA (Docket: A-93-02, II-G-1, Volume V).
- *Description of data reduction and analysis*

The probability of a drilling intrusion encountering pressurized brine is treated as a constant parameter in the CCA. This parameter determines the relative proportion of drilling intrusions into the repository that are expected to also strike pressurized brine in the Castile Formation beneath the WIPP. The parameter is used in the CCDFGF code to determine the probability of an intrusion hitting pressurized brine. The percentage underlain with brine reduces both the frequency and consequences of the E1E2 scenario. Intrusions that strike brine result in higher releases to the accessible environment due to direct brine release, increased likelihood of releases due to spillings, and an increase in the chances of groundwater releases into the Culebra member of the Rustler Formation above the repository.

The CCA documentation for this parameter shows that a constant probability value of 0.080 was used. Supporting documentation for this value is presented in the MASS Attachment 18-6 (Docket: A-93-02, II-G-1, Volume X, Appendix MASS) where a probability of 0.082 is recommended based on semi-variograms and ordinary Kriging analysis of drill hole data.

The geostatistical analysis correlates occurrences of brine reservoirs with disturbed areas of the Castile, using driller-reported brine encounters in a broad area of the

Castile surrounding the WIPP site. The estimated spatial correlation distance for the brine encounter data is smaller than the distance from the disposal site to WIPP-12.

The geostatistical approach ignores the local depth-to-first-conductor data obtained in the TDEM study reported in the 1992 WIPP PA. Given the large uncertainty surrounding the existence of brine in the vicinity of the disposal site, there appears to be little justification for the use of a single fixed percentage for this parameter. However, the Conceptual Models Peer Review Panel considered the impact of a change in the percentage of brine encounters on the overall CCA results to be small.

Other assumptions effect brine pockets in the model. A new feature of the conceptual model introduced for the CCA PA is the assumption that the Castile brine reservoir will experience pressure depletion due to bore holes drilled through both the excavated and unexcavated areas inside the berm. Bore holes which penetrate RH waste areas, the disturbed rock zone, and drift and panel areas also are distinguished in the model.

- *Description of input parameter development*

The index for selecting a brine pocket (ID#3194) is an LHS parameter used in the CCDFGF code. This parameter determines the size of brine pocket that may be encountered in the Castile formation beneath the WIPP. The size of the brine pocket and the initial pressure in the brine pocket are used in the BRAGFLO code to determine the potential for brine flows into the repository after penetration by drilling intrusions.

The documentation for this parameter (Docket: A-93-02, II-G-1, Volume XI, Appendix PAR, p. PAR-113) describes a discrete probability distribution with 32 equally likely integer values ranging from 1 to 32. These values are mapped to one of five possible brine pocket volume values: 32,000, 64,000, 96,000, 128,000 or 160,000 cubic meters. The assigned distribution is highly skewed toward the low end of the size range. A total of 19 of the 32 possible integer value for this variable are assigned to the smallest size brine pocket, 32,000 cubic meters. Ten integers each are assigned to the 64,000 and 96,000 cubic meters size classes. Five integers are assigned to the 128,000 cubic meter size class, and only one integer to the largest 160,000 cubic meters size category. The result is that in less than 20 percent of brine pocket encounters with the two largest size classes: 128,000 or 160,000 cubic meters, with over 80 percent of encounters being of size 96,000

cubic meters or less.

c.5) Any necessary licenses

This consideration is not applicable to the CCDFGF program. No licenses are required.

c.6) An explanation of the manner in which models and computer codes incorporate the effects of parameter correlation.

Parameter correlations for the PA as a whole are introduced in the LHS code, which is also reviewed in Appendix A-6 of this TSD. No correlations are used for parameters unique to the CCDFGF code. The CCDFGF parameters are:

1. Exponential distribution rate parameter.
2. Location in the disposal region.
3. Non-excavated, excavated CH, or excavated RH intrusion.
4. Waste stream encountered.
5. Percentage underlain by pressurized Castile brine.
6. Random selection of plugging pattern.

The CCDFGF parameters are assumed to be mutually independent, and to be independent of the LHS parameters. An assumption of pair-wise independence appears reasonable when considering most pairs in the list above.

Note that the CCDFGF code is structured to allow for correlations between locations in the repository and the probability of encountering brine, because different probabilities may be assigned for each location. However, the input file used in the CCA run has the same probability value for this parameter at all locations.

d) The Administrator or the Administrator's authorized representative may verify results of computer simulations used to support any compliance application by performing independent simulations. Data files, source codes, executable versions of computer software for each model, other material or information needed to permit the Administrator or the Administrator's authorized representative to perform independent simulations, and access to necessary hardware to perform such simulations, shall be provided within 30 calendar days of a request by the

Administrator or the Administrator's authorized representative.

Independent simulation of the tests presented in the VVD was relatively straight-forward, if careful distinction is made between PA96 and PA96_2 input and output files and executables.

- *Ability to access appropriate version of input data files*

Input data files for several generations of the code are available in the CCA-CMS. The appropriate file names are often distinguished by a "_2" in the name. In some cases, this distinction was not clear.

- *Ability to access appropriate version of source codes*

The CCDFGF_PA96 and CCDFGF_PA96_2 source codes are available in the CCA-CMS. The PA96 source code was downloaded to a PC, and an attempt was made to compile the code using Microsoft Fortran Power Station compiler for Windows 95. The Microsoft compiler reported a variety of incompatibilities with the DEC VAX Fortran code. These included unrecognized I/O keywords, such as READONLY, and one keyword name conflict, the use of the Fortran keyword INT to represent an integer variable name.

After correcting these incompatibilities, only one type of error was reported - the use of a double precision function RAN1 using a single precision name in the calling subroutine. This error occurred in the subroutines RWMB, RWDL, RWSURF, RWCULT, and RWCULF.

After consultation with the code's author, it was determined that all five subroutines where the error occurred were not used in the CCDFGF CCA calculations. The subroutines are not reported as dead code in the coverage analysis, because the code was short-circuited by inserting a Return statement as the first executable statement in each subroutine. These subroutines are designed for future use to model Marker Beds, Dewey Lake, and Culebra releases. The newer version of the PA96_2 code does not contain this error.

- *Ability to access appropriate version of executable*

The CCDFGF_PA96 and CCDFGF_PA96_2 executables are available in the CCA-CMS. Test 3 and 4 listed in the VVD were run with both versions of the executable.

- *Sufficient information to permit the verification by performing independent*

simulation

Independent simulations were performed in the replication of the Validation Tests 1, 2, 3 and 4 in the VVD. These tests are discussed in Section b.1.v(9). Analyses also have been performed to implement additional tests discussed in Section b.2(10).

- *Ability to access necessary hardware to perform independent simulations*

Access to the Sandia VAX hardware was available through internet Telnet connections, after obtaining proper authorization.

REFERENCES

Helton, J. C. 1996. *Probability, Conditional Probability, and Complementary Cumulative Distribution Functions in Performance Assessment for Radioactive Waste Disposal*. SAND95-2571, Sandia National Laboratories, Albuquerque, NM, March 1996.

Press, W. H., *et. al.*, 1992. *Numerical Recipes in FORTRAN, the Art of Scientific Computing, 2nd Ed.*, Cambridge University Press, New York, NY, 1992.

See Appendix B for a detailed listing of docket references.

ATTACHMENT 1 - EVAL_ Script Used for Replicate 3 in the Reconstruction of Test 1, Phase 2

REPLICATE 3

```
(Scripts for other phases and replicates of Test 1 were derived from the sa
* File Name:          EVAL_CCGF_OCT96.INP
* Purpose:   Special-case for 10/4/96 snapshot of the CCA for CCGF.
*
* Author:    Mike Williamson, Digital Systems Integration
* Date      Jan 21, 1997
*           Modified March 6, 1997.  Kathy Aragon, Digital Systems Integration
*           Modified March 14, 1997. Kathy Aragon, Digital Systems Integration
*
* Description:  Contains default values for variables (file names, symbols,
*              logicals, parameters) required to start a specific instance
*              run for a CCDFGF code sequence.
*
* Note:        The * character in column 1 indicates the line is a comment.
*              Do not change any value that is in cap's.  Items in capitals
```

* should not be changed by the user. Numerics and items in
* lower case may be changed by trained users.

* The codes/steps that are accessible from this script are:

* EPAUNI_RH
* EPAUNI_CH
* PRECCDFGF
* PRELHS
* LHS
* CCDFGF_1
* CCDFSUM_PLT_1
* CCDFSUM_ADOBE_1

* WARNING - run up through CCDFGF_2 for R1, R2, and R3 before
* running the CCDFSUM steps. CCDFSUM expects output files from
* all 3 replicates and will fail without them.

*-----
* GLOBAL SYMBOLS AND LOGICALS

SYMBOL	UNIQUE_ID	OCT96
SYMBOL	USER_TYPE	EPA
SYMBOL	INPUT_CLASS	oct96
SYMBOL	REPLICATE_NUM	3
SYMBOL	FIRST_CODE	PRELHS
SYMBOL	LAST_CODE	CCDFGF_1
LOGICAL	WORKING_DIR	sys\$login

*Do not change the following value for TOTAL_VECTORS 100

SYMBOL	TOTAL_VECTORS	100
--------	---------------	-----

*END

*EPAUNI_RH

INPUT	eput_wipp_sca.rh	EPU	CCA	NONE	EPU_RH_FILE_INP
OUTPUT	eput_ccgf_cca_crh@.dat	EPU	CREATE	NONE	EPU_RH_FILE_DAT

*END

*EPAUNI_CH

INPUT	eput_waste_st.ch	EPU	CCA	NONE	EPU_CH_FILE_INP
OUTPUT	eput_ccgf_cca_cch@.dat	EPU	CREATE	NONE	EPU_CH_FILE_DAT

*END

*

*

*PRECCDFGF

INPUT CCGF_CCA_CH_TRU.DAT CCGF CCA NONE CH_TRU\$INP
INPUT CCGF_MISC_PRE_CCA.INP CCGF CCA NONE CCGF_MISC\$INP
INPUT CCDFGF.SDB SDB CCA NONE CCGF_SDB\$INP

*

INPUT CCGF_CCA_HT_FRAC.DAT CCGF CCA NONE HT_FRAC\$INP
INPUT SUM_CUSP_CCDFGF_R#_S1_L_T5000.TBL SUM CCA NONE SUM_CUSP_CCGF_CCA\$INP

*

INPUT SUM_PANEL_CCA_CON_R#_S1.TBL SUM CCA NONE SUM_CCDFGF_CCA_CAVGE0D\$INP
INPUT SUM_PANEL_CCA_CON_R#_S2.TBL SUM CCA NONE SUM_CCDFGF_CCA_CAVGE1D\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S1_L_T100.TBL SUM CCA NONE BF4_S1_L_T100\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S1_L_T350.TBL SUM CCA NONE BF4_S1_L_T350\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S1_L_T1000.TBL SUM CCA NONE BF4_S1_L_T1000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S1_L_T3000.TBL SUM CCA NONE BF4_S1_L_T3000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S1_L_T5000.TBL SUM CCA NONE BF4_S1_L_T5000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S1_L_T10000.TBL SUM CCA NONE BF4_S1_L_T10000\$INP

*

INPUT SUM_BF4_CCGF_CCA_R#_S1_U_T100.TBL SUM CCA NONE BF4_S1_U_T100\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S1_U_T350.TBL SUM CCA NONE BF4_S1_U_T350\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S1_U_T1000.TBL SUM CCA NONE BF4_S1_U_T1000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S1_U_T3000.TBL SUM CCA NONE BF4_S1_U_T3000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S1_U_T5000.TBL SUM CCA NONE BF4_S1_U_T5000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S1_U_T10000.TBL SUM CCA NONE BF4_S1_U_T10000\$INP

*

INPUT SUM_BF4_CCGF_CCA_R#_S2_L_T550.TBL SUM CCA NONE BF4_S2_L_T550\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S2_L_T750.TBL SUM CCA NONE BF4_S2_L_T750\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S2_L_T2000.TBL SUM CCA NONE BF4_S2_L_T2000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S2_L_T4000.TBL SUM CCA NONE BF4_S2_L_T4000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S2_L_T10000.TBL SUM CCA NONE BF4_S2_L_T10000\$INP

*

INPUT SUM_BF4_CCGF_CCA_R#_S2_U_T550.TBL SUM CCA NONE BF4_S2_U_T550\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S2_U_T750.TBL SUM CCA NONE BF4_S2_U_T750\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S2_U_T2000.TBL SUM CCA NONE BF4_S2_U_T2000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S2_U_T4000.TBL SUM CCA NONE BF4_S2_U_T4000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S2_U_T10000.TBL SUM CCA NONE BF4_S2_U_T10000\$INP

*

INPUT SUM_BF4_CCGF_CCA_R#_S3_L_T1200.TBL SUM CCA NONE BF4_S3_L_T1200\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S3_L_T1400.TBL SUM CCA NONE BF4_S3_L_T1400\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S3_L_T3000.TBL SUM CCA NONE BF4_S3_L_T3000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S3_L_T5000.TBL SUM CCA NONE BF4_S3_L_T5000\$INP
INPUT SUM_BF4_CCGF_CCA_R#_S3_L_T10000.TBL SUM CCA NONE BF4_S3_L_T10000\$INP

*

INPUT	SUM_BF4_CCGF_CCA_R#_S3_U_T1200.TBL	SUM	CCA NONE	BF4_S3_U_T1200\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S3_U_T1400.TBL	SUM	CCA NONE	BF4_S3_U_T1400\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S3_U_T3000.TBL	SUM	CCA NONE	BF4_S3_U_T3000\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S3_U_T5000.TBL	SUM	CCA NONE	BF4_S3_U_T5000\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S3_U_T10000.TBL	SUM	CCA NONE	BF4_S3_U_T10000\$INP
*				
INPUT	SUM_BF4_CCGF_CCA_R#_S4_L_T550.TBL	SUM	CCA NONE	BF4_S4_L_T550\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S4_L_T750.TBL	SUM	CCA NONE	BF4_S4_L_T750\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S4_L_T2000.TBL	SUM	CCA NONE	BF4_S4_L_T2000\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S4_L_T4000.TBL	SUM	CCA NONE	BF4_S4_L_T4000\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S4_L_T10000.TBL	SUM	CCA NONE	BF4_S4_L_T10000\$INP
*				
INPUT	SUM_BF4_CCGF_CCA_R#_S4_U_T550.TBL	SUM	CCA NONE	BF4_S4_U_T550\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S4_U_T750.TBL	SUM	CCA NONE	BF4_S4_U_T750\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S4_U_T2000.TBL	SUM	CCA NONE	BF4_S4_U_T2000\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S4_U_T4000.TBL	SUM	CCA NONE	BF4_S4_U_T4000\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S4_U_T10000.TBL	SUM	CCA NONE	BF4_S4_U_T10000\$INP
*				
INPUT	SUM_BF4_CCGF_CCA_R#_S5_L_T1200.TBL	SUM	CCA NONE	BF4_S5_L_T1200\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S5_L_T1400.TBL	SUM	CCA NONE	BF4_S5_L_T1400\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S5_L_T3000.TBL	SUM	CCA NONE	BF4_S5_L_T3000\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S5_L_T5000.TBL	SUM	CCA NONE	BF4_S5_L_T5000\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S5_L_T10000.TBL	SUM	CCA NONE	BF4_S5_L_T10000\$INP
*				
INPUT	SUM_BF4_CCGF_CCA_R#_S5_U_T1200.TBL	SUM	CCA NONE	BF4_S5_U_T1200\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S5_U_T1400.TBL	SUM	CCA NONE	BF4_S5_U_T1400\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S5_U_T3000.TBL	SUM	CCA NONE	BF4_S5_U_T3000\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S5_U_T5000.TBL	SUM	CCA NONE	BF4_S5_U_T5000\$INP
INPUT	SUM_BF4_CCGF_CCA_R#_S5_U_T10000.TBL	SUM	CCA NONE	BF4_S5_U_T10000\$INP
*				
INPUT	SUM_CUSP_CCDFGF_R#_S1_L_T100.TBL	SUM	CCA NONE	CUSP_S1_L_T100\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S1_L_T350.TBL	SUM	CCA NONE	CUSP_S1_L_T350\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S1_L_T1000.TBL	SUM	CCA NONE	CUSP_S1_L_T1000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S1_L_T3000.TBL	SUM	CCA NONE	CUSP_S1_L_T3000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S1_L_T5000.TBL	SUM	CCA NONE	CUSP_S1_L_T5000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S1_L_T10000.TBL	SUM	CCA NONE	CUSP_S1_L_T10000\$INP
*				
INPUT	SUM_CUSP_CCDFGF_R#_S1_U_T100.TBL	SUM	CCA NONE	CUSP_S1_U_T100\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S1_U_T350.TBL	SUM	CCA NONE	CUSP_S1_U_T350\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S1_U_T1000.TBL	SUM	CCA NONE	CUSP_S1_U_T1000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S1_U_T3000.TBL	SUM	CCA NONE	CUSP_S1_U_T3000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S1_U_T5000.TBL	SUM	CCA NONE	CUSP_S1_U_T5000\$INP

INPUT	SUM_CUSP_CCDFGF_R#_S1_U_T10000.TBL	SUM	CCA NONE CUSP_S1_U_T10000\$INP
*			
INPUT	SUM_CUSP_CCDFGF_R#_S2_L_T550.TBL	SUM	CCA NONE CUSP_S2_L_T550\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S2_L_T750.TBL	SUM	CCA NONE CUSP_S2_L_T750\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S2_L_T2000.TBL	SUM	CCA NONE CUSP_S2_L_T2000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S2_L_T4000.TBL	SUM	CCA NONE CUSP_S2_L_T4000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S2_L_T10000.TBL	SUM	CCA NONE CUSP_S2_L_T10000\$INP
*			
INPUT	SUM_CUSP_CCDFGF_R#_S2_U_T550.TBL	SUM	CCA NONE CUSP_S2_U_T550\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S2_U_T750.TBL	SUM	CCA NONE CUSP_S2_U_T750\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S2_U_T2000.TBL	SUM	CCA NONE CUSP_S2_U_T2000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S2_U_T4000.TBL	SUM	CCA NONE CUSP_S2_U_T4000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S2_U_T10000.TBL	SUM	CCA NONE CUSP_S2_U_T10000\$INP
*			
INPUT	SUM_CUSP_CCDFGF_R#_S3_L_T1200.TBL	SUM	CCA NONE CUSP_S3_L_T1200\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S3_L_T1400.TBL	SUM	CCA NONE CUSP_S3_L_T1400\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S3_L_T3000.TBL	SUM	CCA NONE CUSP_S3_L_T3000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S3_L_T5000.TBL	SUM	CCA NONE CUSP_S3_L_T5000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S3_L_T10000.TBL	SUM	CCA NONE CUSP_S3_L_T10000\$INP
*			
INPUT	SUM_CUSP_CCDFGF_R#_S3_U_T1200.TBL	SUM	CCA NONE CUSP_S3_U_T1200\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S3_U_T1400.TBL	SUM	CCA NONE CUSP_S3_U_T1400\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S3_U_T3000.TBL	SUM	CCA NONE CUSP_S3_U_T3000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S3_U_T5000.TBL	SUM	CCA NONE CUSP_S3_U_T5000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S3_U_T10000.TBL	SUM	CCA NONE CUSP_S3_U_T10000\$INP
*			
INPUT	SUM_CUSP_CCDFGF_R#_S4_L_T550.TBL	SUM	CCA NONE CUSP_S4_L_T550\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S4_L_T750.TBL	SUM	CCA NONE CUSP_S4_L_T750\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S4_L_T2000.TBL	SUM	CCA NONE CUSP_S4_L_T2000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S4_L_T4000.TBL	SUM	CCA NONE CUSP_S4_L_T4000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S4_L_T10000.TBL	SUM	CCA NONE CUSP_S4_L_T10000\$INP
*			
INPUT	SUM_CUSP_CCDFGF_R#_S4_U_T550.TBL	SUM	CCA NONE CUSP_S4_U_T550\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S4_U_T750.TBL	SUM	CCA NONE CUSP_S4_U_T750\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S4_U_T2000.TBL	SUM	CCA NONE CUSP_S4_U_T2000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S4_U_T4000.TBL	SUM	CCA NONE CUSP_S4_U_T4000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S4_U_T10000.TBL	SUM	CCA NONE CUSP_S4_U_T10000\$INP
*			
INPUT	SUM_CUSP_CCDFGF_R#_S5_L_T1200.TBL	SUM	CCA NONE CUSP_S5_L_T1200\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S5_L_T1400.TBL	SUM	CCA NONE CUSP_S5_L_T1400\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S5_L_T3000.TBL	SUM	CCA NONE CUSP_S5_L_T3000\$INP
INPUT	SUM_CUSP_CCDFGF_R#_S5_L_T5000.TBL	SUM	CCA NONE CUSP_S5_L_T5000\$INP

```

INPUT SUM_CUSP_CCDFGF_R#_S5_L_T10000.TBL  SUM  CCA NONE CUSP_S5_L_T10000$INP
*
INPUT SUM_CUSP_CCDFGF_R#_S5_U_T1200.TBL  SUM  CCA NONE CUSP_S5_U_T1200$INP
INPUT SUM_CUSP_CCDFGF_R#_S5_U_T1400.TBL  SUM  CCA NONE CUSP_S5_U_T1400$INP
INPUT SUM_CUSP_CCDFGF_R#_S5_U_T3000.TBL  SUM  CCA NONE CUSP_S5_U_T3000$INP
INPUT SUM_CUSP_CCDFGF_R#_S5_U_T5000.TBL  SUM  CCA NONE CUSP_S5_U_T5000$INP
INPUT SUM_CUSP_CCDFGF_R#_S5_U_T10000.TBL SUM  CCA NONE CUSP_S5_U_T10000$INP
*
INPUT SUM_ST_CCGF_CCA_R#_S1.TBL           SUM  CCA NONE ALG_ST_CCGF_CCA_S1$INP
INPUT SUM_ST_CCGF_CCA_R#_S2.TBL           SUM  CCA NONE ALG_ST_CCGF_CCA_S2$INP
*
INPUT SUM_NUT_CCGF_CCA_R#_S1.TBL          SUM  CCA NONE SUM_NUTS_S1$INP
INPUT SUM_NUT_CCGF_CCA_R#_S2_T100.TBL     SUM  CCA NONE SUM_NUTS_S2_100$INP
INPUT SUM_NUT_CCGF_CCA_R#_S2_T350.TBL     SUM  CCA NONE SUM_NUTS_S2_350$INP
INPUT SUM_NUT_CCGF_CCA_R#_S3_T1000.TBL    SUM  CCA NONE SUM_NUTS_S3_1000$INP
INPUT SUM_NUT_CCGF_CCA_R#_S3_T3000.TBL    SUM  CCA NONE SUM_NUTS_S3_3000$INP
INPUT SUM_NUT_CCGF_CCA_R#_S3_T5000.TBL    SUM  CCA NONE SUM_NUTS_S3_5000$INP
INPUT SUM_NUT_CCGF_CCA_R#_S3_T7000.TBL    SUM  CCA NONE SUM_NUTS_S3_7000$INP
INPUT SUM_NUT_CCGF_CCA_R#_S3_T9000.TBL    SUM  CCA NONE SUM_NUTS_S3_9000$INP
*
INPUT SUM_NUT_CCGF_CCA_R#_S4_T100.TBL     SUM  CCA NONE SUM_NUTS_S4_100$INP
INPUT SUM_NUT_CCGF_CCA_R#_S4_T350.TBL     SUM  CCA NONE SUM_NUTS_S4_350$INP
INPUT SUM_NUT_CCGF_CCA_R#_S5_T1000.TBL    SUM  CCA NONE SUM_NUTS_S5_1000$INP
INPUT SUM_NUT_CCGF_CCA_R#_S5_T3000.TBL    SUM  CCA NONE SUM_NUTS_S5_3000$INP
INPUT SUM_NUT_CCGF_CCA_R#_S5_T5000.TBL    SUM  CCA NONE SUM_NUTS_S5_5000$INP
INPUT SUM_NUT_CCGF_CCA_R#_S5_T7000.TBL    SUM  CCA NONE SUM_NUTS_S5_7000$INP
INPUT SUM_NUT_CCGF_CCA_R#_S5_T9000.TBL    SUM  CCA NONE SUM_NUTS_S5_9000$INP
*
INPUT SUM_PANEL_CCDFGF_R#_S6_100.TBL      SUM  CCA NONE SUM_PNL_S6_100$INP
INPUT SUM_PANEL_CCDFGF_R#_S6_350.TBL      SUM  CCA NONE SUM_PNL_S6_350$INP
INPUT SUM_PANEL_CCDFGF_R#_S6_1000.TBL     SUM  CCA NONE SUM_PNL_S6_1000$INP
INPUT SUM_PANEL_CCDFGF_R#_S6_2000.TBL     SUM  CCA NONE SUM_PNL_S6_2000$INP
INPUT SUM_PANEL_CCDFGF_R#_S6_4000.TBL     SUM  CCA NONE SUM_PNL_S6_4000$INP
INPUT SUM_PANEL_CCDFGF_R#_S6_6000.TBL     SUM  CCA NONE SUM_PNL_S6_6000$INP
INPUT SUM_PANEL_CCDFGF_R#_S6_9000.TBL     SUM  CCA NONE SUM_PNL_S6_9000$INP
*
INPUT SUM_ST2D3_CCGF_CCA_R#_PM.TBL        SUM  CCA NONE ST2D3_CCA_PM$INP
INPUT SUM_ST2D3_CCGF_CCA_R#_FM.TBL        SUM  CCA NONE ST2D3_CCA_FM$INP
*
OUTPUT CCGF_CCDFGF_CCA_r#@.out            EPA_CCGF CREATE NONE CCGF_PRT$OUT
OUTPUT CCGF_CCA_r#@.OUT                   EPA_CCGF CREATE NONE CCGF$OUT
OUTPUT CCGF_CUTTING_CCA_R#@.TRN          CCGF      CREATE NONE CCGF_CUTTING$OUT

```

```

OUTPUT CCGF_BLOWOUT_CCA_R#@.TRN      EPA_CCGF CREATE NONE CCGF_BLOWOUT$OUT
OUTPUT CCGF_SPALLING_CCA_R#@.TRN     EPA_CCGF CREATE NONE CCGF_SPALLING$OUT
OUTPUT CCGF_NUT_CCA_R#@.TRN          EPA_CCGF CREATE NONE CCGF_NUTS$OUT
OUTPUT CCGF_SECOTP_CCA_R#@.TRN       EPA_CCGF CREATE NONE CCGF_SECOTP$OUT
OUTPUT CCGF_RELTAB_CCA_R#@.DAT       EPA_CCGF CREATE EPA_CCGF CCGF_RELTAB$OUT
*
*END
*
*PRELHS
SYMBOL          LHSDB          WIPP::WIPP_DB
SYMBOL          LHSCALC         CCA9
INPUT  lhs1_ccgf_r#.inp          LHS  CCA      NONE  LHS1_FILE_INP
OUTPUT lhs1_ccgf_trn_r#@.out     LHS  CREATE  NONE  LHS1_FILE_TRN
OUTPUT lhs1_ccgf_r#@.out         LHS  CREATE  NONE  LHS1_FILE_OUT
*END
*
*LHS
OUTPUT lhs2_ccgf_trn_r#@.out     LHS  CREATE  NONE  LHS2_FILE_TRN
OUTPUT lhs2_ccgf_dbg_r#@.out     LHS  CREATE  NONE  LHS2_FILE_DBG
*END
*
*
*CCDFGF_1
INPUT  ccgf_misc_postcca_verbos_1.inp  CCGF  CCA  NONE  CCGF_1_MISC_FILE_INP
INPUT  ccgf_node3_cca.inp              CCGF  CCA  NONE  CCGF_1_NODE3_FILE_INP
INPUT  ccgf_inv5_cca.inp               CCGF  CCA  NONE  CCGF_1_INV5_FILE_INP
INPUT  ccgf_region_cca.inp             CCGF  CCA  NONE  CCGF_1_REGION_FILE_INP
INPUT  CCDFGF.SDB                      SDB   CCA  NONE  CCGF_1_SDB_FILE_INP
INPUT  ccgf_reltab_cca_R#@.dat         EPA_CCGF EPA  NONE  CCGF_1_RELTAB_FILE_INP
OUTPUT ccgf_ccdfgf_r#_1@.out          CCGF  CREATE EPA_CCGF CCGF_1_FILE_PRT
OUTPUT ccgf_r#_1@.out                 CCGF  CREATE EPA_CCGF CCGF_1_FILE_OUT
*END
*
*
*CCDFSUM_PLT_1
INPUT  ccgf_r1_1@.out  EPA_CCGF EPA NONE CCDFSUM_FILE_INP1
INPUT  ccgf_r2_1@.out  EPA_CCGF EPA NONE CCDFSUM_FILE_INP2
INPUT  ccgf_r3_1@.out  EPA_CCGF EPA NONE CCDFSUM_FILE_INP3
INPUT  ccgf_ccdfsum_cca.inp          CCGF      CCA NONE CCDFSUM_PLT_1_FILE_INP
OUTPUT ccgf_ccdfsum_1a@.out CCGF  CREATE EPA_CCGF CCDFSUM_PLT_1_FILE_OUT
*END
*

```

```

*CCDFSUM_ADOBE_1
  INPUT  ccgf ccdsum cca.inp          CCGF CCA    NONE    CCDFSUM ADOBE 1
  OUTPUT ccgf_ccdsum_1@.pi    CCGF CREATE EPA_CCGF CCDFSUM_ADOBE_1_FILE_TMP
  OUTPUT ccgf_ccdsum_1@.pi_* CCGF CREATE EPA_CCGF CCDFSUM_ADOBE_1_FILE_OUT
*END
*
*-----
*Substitutions are preformed in file names (INPUT and OUTPUT records only)
*as follows:
*  # - replicate number ( 1,2,3 )
*  + - substitute with local node name (used for node name based
*      disk names like disk$beatle_ccal.
*  @ - id field to be added at run time, depending on the value of unique_id.
*      When the symbol "unique_id" is provided (in the first group of symbols,
*      that will be used for the id field. This allows users to run
*      partial jobs, using unique id's, and later run additional steps.
*      The old time stamp will be put into the new steps to keep names
*      consistent.
*
* Record types and layouts - all fields are delimited with spaces or tabs.
*
* SYMBOL param_name param_value
*   param_name      - symbol name to be created
*   param_value     - symbol value to be assigned
*
* LOGICAL
*   logical_name    - logical name to be created
*   logical_value   - logical value to be assigned.
*
* INPUT
* OUTPUT
*   file_name       - File name
*   code_prefix     - The code prefix assigned by the CMS librarian.
*   file_loc        - CCA, EPA,WORKING_DIR.
*   file_disp       - NONE, EPA_XXX. If the file is to be
*                   stored in CMS after the run.
*   file_id         - Symbol used in the program, do not change.
*   dependencies    - list of downstream codes that use the file
*                   (if any), this is only used for documentation.
*-----

```

OUTPUTS FROM THE DIFFERENCE PROGRAM COMPARING THE CMS AND RECONSTRUCTED VERSIONS OF THE TEST 1 OUTPUT

FILES

TEST 1, PHASE 1, REPLICATE 1

Number of difference sections found: 0

Number of difference records found: 0

```
DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=$2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]RELT1 DIF
    $2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]RELTABR1.DAT;1-
    $2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]RELTABR1.NEW;1
```

TEST 1, PHASE 1, REPLICATE 2

Number of difference sections found: 0

Number of difference records found: 0

```
DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=$2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]RELT2 DIF
    $2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]RELTABR2.DAT;1-
    $2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]RELTABR2.NEW;1
```

TEST 1, PHASE 1, REPLICATE 3

Number of difference sections found: 0

Number of difference records found: 0

```
DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=$2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]RELT3 DIF
    $2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]RELTABR3.DAT;1-
    $2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]RELTABR3.NEW;1
```

OUTPUTS FROM THE DIFFERENCE PROGRAM COMPARING THE CMS AND RECONSTRUCTED VERSIONS OF THE TEST 1 OUTPUT FILES

TEST 1, PHASE 2, REPLICATE 1

Number of difference sections found: 0

Number of difference records found: 0

```
DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=$2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFGF_1]C
    $2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFGF_1]CCGF_POSTCCA_R1_VERBOSE_1.OUT;1-
    $2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFGF_1]CCGF_R1_1_OCT96.OUT;1
```

TEST 1, PHASE 2, REPLICATE 2

Number of difference sections found: 0

Number of difference records found: 0

```
DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=$2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFGF_1]C
    $2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFGF_1]CCGF_POSTCCA_R2_VERBOSE_1.OUT;1-
    $2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFGF_1]CCGF_R2_1_OCT96.OUT;1
```

TEST 1, PHASE 2, REPLICATE 3

Number of difference sections found: 0

Number of difference records found: 0

```
DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=$2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFGF 1]C
$2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFGF_1]CCGF_POSTCCA_R3_VERBOSE_1.OUT;1-
$2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFGF_1]CCGF_R3_1_OCT96.OUT;1
```

TEST 1, PHASE 3

Number of difference sections found: 0

Number of difference records found: 0

```
DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=$2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFSUM PL
$2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFSUM_PLT]CCGF_CCDFSUM_1A_OCT96.OUT;2-
$2$DKB400:[ROOT.HJCHMEL.TESTCMS.CCDFSUM PLT]CCGF_CCDFSUM_POSTCCA_VERBOSE_1A.P
```

OUTPUT FROM THE DIFFERENCE PROGRAM COMPARING THE CMS AND RECONSTRUCTED VERSIONS OF THE TEST 2 OUTPUT FILE

TEST 2

Number of difference sections found: 0

Number of difference records found: 0

```
DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=$2$DKB400:[ROOT.HJCHMEL.DOUBLE R]CCGF DIFF
$2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]CCGF_T2_PA96.OUT;1-
$2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]CCGF_T2_PA96.NEW;1
```

INPUT FILES FOR THE RECONSTRUCTION OF TEST 1

CCGF_MISC_POSTCCA_VERBOSE_1.INP

```
TEST CASE FOR WIPP DRILLING INTRUSION SCENARIO
(SECOND TITLE RECORD)
3 10000 NUMBER OF OBS, NUMBER OF FUTURES PER OBS
0 0 2 1 OPTIONS (0=NORMAL,1=PREPROC)(0=TABLES,1=GRIDFLO)(1=VAR,2=CONST)(1
1 3 NUMBER OF OBS FOR DETAILED PRINT, OBS INDICES
40 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
29 30 31 32 33 34 35 36 37 38 39 40 NUMBER OF FUTURES FOR DETAILED PRINT, FUTURE
100. 0.0 INITIAL AND SUBSEQUENT ADMIN CONTROL TIMES (YR)
100. 10000. 1.0E6 1.0E6 TS LIMIT (YR), END TIME (YR), RESET TS (YR), PRT FRQ
4.07E6 TOTAL ACTIVITY IN REPOSITORY (CI)
0.6285 TOTAL AREA OF DISPOSAL REGION (KM2)
1.632E7 TOTAL MASS OF SOLIDS IN REPOSITORY (KG)
823. 140. ELEVATIONS (M) FOR CULEBRA AND CASTILLE
87. 1078. PRESSURE HEADS (M) FOR CULEBRA AND CASTILLE
46.8 10000. 600. 0.01 NUMBER OF INTRUSIONS, TIME PERIOD (YR), TRANSITION TIME
1.00E-4 600. 0.01 MINING INTRUSION RATE (1/YR), TRANSITION TIME (YR), INITIA
0.31115 0.31115 0.31115 BOREHOLE DIAMETER RANGE AND MODE ABOVE REPOSITORY (M)
0.31115 0.31115 0.31115 BOREHOLE DIAMETER RANGE AND MODE BELOW REPOSITORY (M)
1.0E-9 1.0E-9 1.0E-9 BOREHOLE PERMEABILITY RANGE AND MODE ABOVE REPOSITORY
1.0E-9 1.0E-9 1.0E-9 BOREHOLE PERMEABILITY RANGE AND MODE BELOW REPOSITORY
```

```

1230.          BRINE DENSITY (KG/M3)
1.8E-3        BRINE VISCOSITY (KG/M/S)
1            NUMBER OF REGIONS
0.0 1.115E5 1.576E4  REGION 1 PENETRATION PROB EACH WASTE TYPE (NONE,CH,RH)
3 1          NUMBER OF WASTE STREAMS TO AVG FOR CH WASTES AND RH WASTES
1          NUMBER OF BRINE POCKETS
31 1000      LHS VAR DEplete INDEX (0=LHS NOT USED), NUMBER OF INTRUSIONS
0.02 0.68 0.30 PLUGGING PATTERN PROBABILITIES (MUST BE 3 VALUES)
0.50        CUTOFF FRACTION FOR BUFFER SOLUBILITY LIMIT EFFECT
0          1000 SPALLINGS REFERENCE (1=AFTER E1) AND NUMBER OF INTRUSIONS
0          1000 BLOWOUT REFERENCE (1=AFTER E1) AND NUMBER OF INTRUSIONS
9.80665     ACCELERATION DUE TO GRAVIY (M/S2)
3.14159     PI
-1701       RANDOM NUMBER GENERATOR SEED (MUST BE NEGATIVE)
1.0E-6      RELATIVE ROUNDOFF TOLERANCE
1.0E-10     RELATIVE PRESSURE TOLERANCE

```

INPUT FILES FOR THE RECONSTRUCTION OF TEST 2

CCGF_MISC_T2.INP

```

TEST CASE FOR WIPP DRILLING INTRUSION SCENARIO
(SECOND TITLE RECORD)
3 10000      NUMBER OF OBS, NUMBER OF FUTURES PER OBS
0 0 2 1     OPTIONS (0=NORMAL,1=PREPROC)(0=TABLES,1=GRIDFLO)(1=VAR,2=CONST)(1
1 3         NUMBER OF OBS FOR DETAILED PRINT, OBS INDICES
40 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
29 30 31 32 33 34 35 36 37 38 39 40 NUMBER OF FUTURES FOR DETAILED PRINT, FUTURE
100. 0.0    INITIAL AND SUBSEQUENT ADMIN CONTROL TIMES (YR)
100. 10000. 1.0E6 1.0E6 TS LIMIT (YR), END TIME (YR), RESET TS (YR), PRT FRQ
4.07E6     TOTAL ACTIVITY IN REPOSITORY (CI)
0.6285     TOTAL AREA OF DISPOSAL REGION (KM2)
1.632E7    TOTAL MASS OF SOLIDS IN REPOSITORY (KG)
823.      140. ELEVATIONS (M) FOR CULEBRA AND CASTILLE
87.       1078. PRESSURE HEADS (M) FOR CULEBRA AND CASTILLE
46.8 10000. 600. 0.01 NUMBER OF INTRUSIONS, TIME PERIOD (YR), TRANSITION TIME
1.00E-4 600. 0.01 MINING INTRUSION RATE (1/YR), TRANSITION TIME (YR), INITIA
0.31115 0.31115 0.31115 BOREHOLE DIAMETER RANGE AND MODE ABOVE REPOSITORY (M)
0.31115 0.31115 0.31115 BOREHOLE DIAMETER RANGE AND MODE BELOW REPOSITORY (M)
1.0E-9 1.0E-9 1.0E-9 BOREHOLE PERMEABILITY RANGE AND MODE ABOVE REPOSITORY
1.0E-9 1.0E-9 1.0E-9 BOREHOLE PERMEABILITY RANGE AND MODE BELOW REPOSITORY
1230.          BRINE DENSITY (KG/M3)
1.8E-3        BRINE VISCOSITY (KG/M/S)
1            NUMBER OF REGIONS

```

0.0 1.115E5 1.576E4 REGION 1 PENETRATION PROB EACH WASTE TYPE (NONE,CH,RH)
3 1 NUMBER OF WASTE STREAMS TO AVG FOR CH WASTES AND RH WASTES
1 NUMBER OF BRINE POCKETS
31 1000 LHS VAR DEplete INDEX (0=LHS NOT USED), NUMBER OF INTRUSIONS
0.02 0.68 0.30 PLUGGING PATTERN PROBABILITIES (MUST BE 3 VALUES)
0.50 CUTOFF FRACTION FOR BUFFER SOLUBILITY LIMIT EFFECT
0 1000 SPALLINGS REFERENCE (1=AFTER E1) AND NUMBER OF INTRUSIONS
0 1000 BLOWOUT REFERENCE (1=AFTER E1) AND NUMBER OF INTRUSIONS
9.80665 ACCELERATION DUE TO GRAVIY (M/S2)
3.14159 PI
-1701 RANDOM NUMBER GENERATOR SEED (MUST BE NEGATIVE)
1.0E-6 RELATIVE ROUND OFF TOLERANCE
1.0E-10 RELATIVE PRESSURE TOLERANCE
INPUT FILES FOR THE RECONSTRUCTION OF TEST 3
CCGF_MISC_T3.INP
TEST CASE FOR WIPP DRILLING INTRUSION SCENARIO
(SECOND TITLE RECORD)
3 10000 NUMBER OF OBS, NUMBER OF FUTURES PER OBS
0 0 2 1 OPTIONS (0=NORMAL,1=PREPROC)(0=TABLES,1=GRIDFLO)(1=VAR,2=CONST)(1
1 3 NUMBER OF OBS FOR DETAILED PRINT, OBS INDICES
40 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
29 30 31 32 33 34 35 36 37 38 39 40 NUMBER OF FUTURES FOR DETAILED PRINT, FUTURE
100. 0.0 INITIAL AND SUBSEQUENT ADMIN CONTROL TIMES (YR)
100. 10000. 1.0E6 1.0E6 TS LIMIT (YR), END TIME (YR), RESET TS (YR), PRT FRQ
4.07E6 TOTAL ACTIVITY IN REPOSITORY (CI)
0.6285 TOTAL AREA OF DISPOSAL REGION (KM2)
1.632E7 TOTAL MASS OF SOLIDS IN REPOSITORY (KG)
823. 140. ELEVATIONS (M) FOR CULEBRA AND CASTILLE
87. 1078. PRESSURE HEADS (M) FOR CULEBRA AND CASTILLE
46.8 10000. 600. 0.01 NUMBER OF INTRUSIONS, TIME PERIOD (YR), TRANSITION TIME
1.00E-4 600. 0.01 MINING INTRUSION RATE (1/YR), TRANSITION TIME (YR), INITIA
0.31115 0.31115 0.31115 BOREHOLE DIAMETER RANGE AND MODE ABOVE REPOSITORY (M)
0.31115 0.31115 0.31115 BOREHOLE DIAMETER RANGE AND MODE BELOW REPOSITORY (M)
1.0E-9 1.0E-9 1.0E-9 BOREHOLE PERMEABILITY RANGE AND MODE ABOVE REPOSITORY
1.0E-9 1.0E-9 1.0E-9 BOREHOLE PERMEABILITY RANGE AND MODE BELOW REPOSITORY
1230. BRINE DENSITY (KG/M3)
1.8E-3 BRINE VISCOSITY (KG/M/S)
1 NUMBER OF REGIONS
0.0 1.115E5 1.576E4 REGION 1 PENETRATION PROB EACH WASTE TYPE (NONE,CH,RH)
3 1 NUMBER OF WASTE STREAMS TO AVG FOR CH WASTES AND RH WASTES
1 NUMBER OF BRINE POCKETS
31 1000 LHS VAR DEplete INDEX (0=LHS NOT USED), NUMBER OF INTRUSIONS

0.02 0.68 0.30 PLUGGING PATTERN PROBABILITIES (MUST BE 3 VALUES)
 0.50 CUTOFF FRACTION FOR BUFFER SOLUBILITY LIMIT EFFECT
 0 1000 SPALLINGS REFERENCE (1=AFTER E1) AND NUMBER OF INTRUSIONS
 0 1000 BLOWOUT REFERENCE (1=AFTER E1) AND NUMBER OF INTRUSIONS
 9.80665 ACCELERATION DUE TO GRAVITY (M/S²)
 3.14159 PI
 -1701 RANDOM NUMBER GENERATOR SEED (MUST BE NEGATIVE)
 1.0E-6 RELATIVE ROUNDOFF TOLERANCE
 1.0E-10 RELATIVE PRESSURE TOLERANCE

INPUT FILES FOR THE RECONSTRUCTION OF TEST 4

CCGF_MISC_T4.INP

TEST CASE FOR WIPP DRILLING INTRUSION SCENARIO
 (SECOND TITLE RECORD)

1 20 NUMBER OF OBS, NUMBER OF FUTURES PER OBS
 0 0 2 1 OPTIONS (0=NORMAL,1=PREPROC)(0=TABLES,1=GRIDFLO)(1=VAR,2=CONST)(1
 1 1 NUMBER OF OBS FOR DETAILED PRINT, OBS INDICES
 20 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 NUMBER OF FUTURES FOR D
 100. 0.0 INITIAL AND SUBSEQUENT ADMIN CONTROL TIMES (YR)
 100. 10000. 1.0E6 1.0E6 TS LIMIT (YR), END TIME (YR), RESET TS (YR), PRT FRQ
 4.07E6 TOTAL ACTIVITY IN REPOSITORY (CI)
 0.6285 TOTAL AREA OF DISPOSAL REGION (KM²)
 1.632E7 TOTAL MASS OF SOLIDS IN REPOSITORY (KG)
 823. 140. ELEVATIONS (M) FOR CULEBRA AND CASTILLE
 87. 1078. PRESSURE HEADS (M) FOR CULEBRA AND CASTILLE
 46.8 10000. 600. 0.01 NUMBER OF INTRUSIONS, TIME PERIOD (YR), TRANSITION TIME
 1.00E-4 600. 0.01 MINING INTRUSION RATE (1/YR), TRANSITION TIME (YR), INITIA
 0.31115 0.31115 0.31115 BOREHOLE DIAMETER RANGE AND MODE ABOVE REPOSITORY (M)
 0.31115 0.31115 0.31115 BOREHOLE DIAMETER RANGE AND MODE BELOW REPOSITORY (M)
 1.0E-9 1.0E-9 1.0E-9 BOREHOLE PERMEABILITY RANGE AND MODE ABOVE REPOSITORY
 1.0E-9 1.0E-9 1.0E-9 BOREHOLE PERMEABILITY RANGE AND MODE BELOW REPOSITORY
 1230. BRINE DENSITY (KG/M³)
 1.8E-3 BRINE VISCOSITY (KG/M/S)
 1 NUMBER OF REGIONS
 0.0 1.115E5 1.576E4 REGION 1 PENETRATION PROB EACH WASTE TYPE (NONE,CH,RH)
 3 1 NUMBER OF WASTE STREAMS TO AVG FOR CH WASTES AND RH WASTES
 1 NUMBER OF BRINE POCKETS
 31 1000 LHS VAR DEplete INDEX (0=LHS NOT USED), NUMBER OF INTRUSIONS
 0.02 0.68 0.30 PLUGGING PATTERN PROBABILITIES (MUST BE 3 VALUES)
 0.50 CUTOFF FRACTION FOR BUFFER SOLUBILITY LIMIT EFFECT
 0 2 SPALLINGS REFERENCE (1=AFTER E1) AND NUMBER OF INTRUSIONS
 0 3 BLOWOUT REFERENCE (1=AFTER E1) AND NUMBER OF INTRUSIONS

9.80665 ACCELERATION DUE TO GRAVITY (M/S2)
 3.14159 PI
 -1701 RANDOM NUMBER GENERATOR SEED (MUST BE NEGATIVE)
 1.0E-6 RELATIVE ROUNDOFF TOLERANCE
 1.0E-10 RELATIVE PRESSURE TOLERANCE

AUXILIARY INPUT FILES FOR THE RECONSTRUCTION OF TESTS 1, 2, 3, AND 4

CCGF_INV5_CCA.INP

DRILLING INTRUSION INVENTORY

(SPECIES, DESCEND, ACT(CI) or MASS(KG), THALF(Y), MW, EPALIM, MBC(KG/M3) or KD(KG/KG) RANGE,

MG	NONE	4.86E7	0.0	40.3	0.0	0.243	0.243	1.0
AM241	NP237	7.15E5	4.32E2	241	100.	0.239E-5	0.239E-1	1.0
NP237	U233	2.08E1	2.14E6	237	100.	0.239E-6	0.239E-4	1.0
U233	TH229	1.53E3	1.59E5	233	100.	0.239E-4	0.239E-2	1.0
TH229	NONE	0.0	7.43E3	229	100.	0.239E-5	0.239E-4	1.0

Note: The values in this file are not used in the current version of the CCDFGF p

AUXILIARY INPUT FILES FOR THE RECONSTRUCTION OF TESTS 1, 2, 3, AND 4

CCGF_NODE3_CCA.INP

NODE DEFINITIONS FOR WIPP REPOSITORY (M) (7/17/95)										(X1,X2,Y1,Y2,H,W,K,PF,WF
495.0	1204.0	5.0	5.0	3.96	10.0	6.70E-7	0.400	1.0	384.	TOTAL HORIZO
495.0	1204.0	106.5	106.5	3.96	10.0	6.70E-7	0.400	1.0	384.	
495.0	1204.0	177.5	177.5	3.96	10.0	6.70E-7	0.400	1.0	384.	
495.0	1204.0	279.0	279.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
495.0	1204.0	319.0	319.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
495.0	1204.0	420.5	420.5	3.96	10.0	6.70E-7	0.400	1.0	384.	
495.0	1204.0	491.5	491.5	3.96	10.0	6.70E-7	0.400	1.0	384.	
495.0	1204.0	593.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
495.0	495.0	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	TOTAL VERTIC
535.5	535.5	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
576.0	576.0	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
616.5	616.5	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
657.0	657.0	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
697.5	697.5	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
738.0	738.0	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
778.0	778.0	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
824.5	824.5	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
877.0	877.0	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
921.0	921.0	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	

961.0	961.0	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
1001.5	1001.5	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
1042.0	1042.0	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
1082.5	1082.5	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
1123.0	1123.0	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
1163.5	1163.5	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
1204.0	1204.0	5.0	593.0	3.96	10.0	6.70E-7	0.400	1.0	384.	
778.0	921.0	5.0	5.0	3.96	6.4	6.70E-7	0.400	1.0	384.	REDEFINE PAN
778.0	921.0	106.5	106.5	3.96	4.3	6.70E-7	0.400	1.0	384.	
778.0	921.0	177.5	177.5	3.96	6.4	6.70E-7	0.400	1.0	384.	
778.0	921.0	279.0	279.0	3.96	4.3	6.70E-7	0.400	1.0	384.	
778.0	921.0	319.0	319.0	3.96	6.4	6.70E-7	0.400	1.0	384.	
778.0	921.0	420.5	420.5	3.96	4.3	6.70E-7	0.400	1.0	384.	
778.0	921.0	491.5	491.5	3.96	6.4	6.70E-7	0.400	1.0	384.	
778.0	921.0	593.0	593.0	3.96	6.1	6.70E-7	0.400	1.0	384.	
738.0	778.0	5.0	5.0	3.96	6.4	6.70E-09	1.0	0.0	384.	REDEFINE SHA
738.0	778.0	106.5	106.5	3.96	4.3	6.70E-09	1.0	0.0	384.	
738.0	778.0	177.5	177.5	3.96	6.4	6.70E-09	1.0	0.0	384.	
738.0	778.0	279.0	279.0	3.96	4.3	6.70E-09	1.0	0.0	384.	
738.0	778.0	319.0	319.0	3.96	6.4	6.70E-09	1.0	0.0	384.	
738.0	778.0	420.5	420.5	3.96	4.3	6.70E-09	1.0	0.0	384.	
738.0	778.0	491.5	491.5	3.96	6.4	6.70E-09	1.0	0.0	384.	
738.0	778.0	593.0	593.0	3.96	6.1	6.70E-09	1.0	0.0	384.	
921.0	961.0	5.0	5.0	3.96	6.4	6.70E-09	1.0	0.0	384.	
921.0	961.0	106.5	106.5	3.96	4.3	6.70E-09	1.0	0.0	384.	
921.0	961.0	177.5	177.5	3.96	6.4	6.70E-09	1.0	0.0	384.	
921.0	961.0	279.0	279.0	3.96	4.3	6.70E-09	1.0	0.0	384.	
921.0	961.0	319.0	319.0	3.96	6.4	6.70E-09	1.0	0.0	384.	
921.0	961.0	420.5	420.5	3.96	4.3	6.70E-09	1.0	0.0	384.	
921.0	961.0	491.5	491.5	3.96	6.4	6.70E-09	1.0	0.0	384.	
921.0	961.0	593.0	593.0	3.96	6.1	6.70E-09	1.0	0.0	384.	
778.0	778.0	279.0	319.0	3.96	4.3	6.70E-09	1.0	0.0	384.	
824.5	824.5	279.0	319.0	3.96	4.3	6.70E-09	1.0	0.0	384.	
877.0	877.0	279.0	319.0	3.96	7.6	6.70E-09	1.0	0.0	384.	
921.0	921.0	279.0	319.0	3.96	4.3	6.70E-09	1.0	0.0	384.	
490.0	770.0	110.0	170.0	0.00	0.0	0.0	0.0	0.0	384.	REDEFINE REG
490.0	770.0	290.0	310.0	0.00	0.0	0.0	0.0	0.0	384.	
490.0	770.0	430.0	480.0	0.00	0.0	0.0	0.0	0.0	384.	
930.0	1210.0	110.0	170.0	0.00	0.0	0.0	0.0	0.0	384.	
930.0	1210.0	290.0	310.0	0.00	0.0	0.0	0.0	0.0	384.	
930.0	1210.0	430.0	480.0	0.00	0.0	0.0	0.0	0.0	384.	

AUXILIARY INPUT FILES FOR THE RECONSTRUCTION OF TESTS 1, 2,

3, AND 4

CCGF_REGION_CCA.INP

REGION, PANEL, BRINE POCKET, AREA FRACTION, EXCAVATED AREA FRACTION, BRN PCKT PRO								
X-NODE	Y-NODE	REGION	PANEL	LOW/UP	BRNPCK	FRCTOTAREA	FRCEXCAREA	P(BP)
1	1	1	5	1	1	0.006944	0.2091	0.08
2	1	1	5	1	1	0.006944	0.2091	0.08
3	1	1	5	1	1	0.006944	0.2091	0.08
4	1	1	5	1	1	0.006944	0.2091	0.08
5	1	1	5	1	1	0.006944	0.2091	0.08
6	1	1	5	1	1	0.006944	0.2091	0.08
7	1	1	5	1	1	0.006944	0.2091	0.08
8	1	1	10	1	1	0.006944	0.2091	0.08
9	1	1	10	1	1	0.006944	0.2091	0.08
10	1	1	10	1	1	0.006944	0.2091	0.08
11	1	1	10	1	1	0.006944	0.2091	0.08
12	1	1	4	1	1	0.006944	0.2091	0.08
13	1	1	4	1	1	0.006944	0.2091	0.08
14	1	1	4	1	1	0.006944	0.2091	0.08
15	1	1	4	1	1	0.006944	0.2091	0.08
16	1	1	4	1	1	0.006944	0.2091	0.08
17	1	1	4	1	1	0.006944	0.2091	0.08
18	1	1	4	1	1	0.006944	0.2091	0.08
1	2	1	5	1	1	0.006944	0.2091	0.08
2	2	1	5	1	1	0.006944	0.2091	0.08
3	2	1	5	1	1	0.006944	0.2091	0.08
4	2	1	5	1	1	0.006944	0.2091	0.08
5	2	1	5	1	1	0.006944	0.2091	0.08
6	2	1	5	1	1	0.006944	0.2091	0.08
7	2	1	5	1	1	0.006944	0.2091	0.08
8	2	1	10	1	1	0.006944	0.2091	0.08
9	2	1	10	1	1	0.006944	0.2091	0.08
10	2	1	10	1	1	0.006944	0.2091	0.08
11	2	1	10	1	1	0.006944	0.2091	0.08
12	2	1	4	1	1	0.006944	0.2091	0.08
13	2	1	4	1	1	0.006944	0.2091	0.08
14	2	1	4	1	1	0.006944	0.2091	0.08
15	2	1	4	1	1	0.006944	0.2091	0.08
16	2	1	4	1	1	0.006944	0.2091	0.08
17	2	1	4	1	1	0.006944	0.2091	0.08
18	2	1	4	1	1	0.006944	0.2091	0.08
1	3	1	6	2	1	0.006944	0.2091	0.08

2	3	1	6	2	1	0.006944	0.2091	0.08
3	3	1	6	2	1	0.006944	0.2091	0.08
4	3	1	6	2	1	0.006944	0.2091	0.08
5	3	1	6	2	1	0.006944	0.2091	0.08
6	3	1	6	2	1	0.006944	0.2091	0.08
7	3	1	6	2	1	0.006944	0.2091	0.08
8	3	1	10	1	1	0.006944	0.2091	0.08
9	3	1	10	1	1	0.006944	0.2091	0.08
10	3	1	10	1	1	0.006944	0.2091	0.08
11	3	1	10	1	1	0.006944	0.2091	0.08
12	3	1	3	2	1	0.006944	0.2091	0.08
13	3	1	3	2	1	0.006944	0.2091	0.08
14	3	1	3	2	1	0.006944	0.2091	0.08
15	3	1	3	2	1	0.006944	0.2091	0.08
16	3	1	3	2	1	0.006944	0.2091	0.08
17	3	1	3	2	1	0.006944	0.2091	0.08
18	3	1	3	2	1	0.006944	0.2091	0.08
1	4	1	6	2	1	0.006944	0.2091	0.08
2	4	1	6	2	1	0.006944	0.2091	0.08
3	4	1	6	2	1	0.006944	0.2091	0.08
4	4	1	6	2	1	0.006944	0.2091	0.08
5	4	1	6	2	1	0.006944	0.2091	0.08
6	4	1	6	2	1	0.006944	0.2091	0.08
7	4	1	6	2	1	0.006944	0.2091	0.08
8	4	1	10	1	1	0.006944	0.2091	0.08
9	4	1	10	1	1	0.006944	0.2091	0.08
10	4	1	10	1	1	0.006944	0.2091	0.08
11	4	1	10	1	1	0.006944	0.2091	0.08
12	4	1	3	2	1	0.006944	0.2091	0.08
13	4	1	3	2	1	0.006944	0.2091	0.08
14	4	1	3	2	1	0.006944	0.2091	0.08
15	4	1	3	2	1	0.006944	0.2091	0.08
16	4	1	3	2	1	0.006944	0.2091	0.08
17	4	1	3	2	1	0.006944	0.2091	0.08
18	4	1	3	2	1	0.006944	0.2091	0.08
1	5	1	7	2	1	0.006944	0.2091	0.08
2	5	1	7	2	1	0.006944	0.2091	0.08
3	5	1	7	2	1	0.006944	0.2091	0.08
4	5	1	7	2	1	0.006944	0.2091	0.08
5	5	1	7	2	1	0.006944	0.2091	0.08
6	5	1	7	2	1	0.006944	0.2091	0.08
7	5	1	7	2	1	0.006944	0.2091	0.08

8	5	1	9	2	1	0.006944	0.2091	0.08
9	5	1	9	2	1	0.006944	0.2091	0.08
10	5	1	9	2	1	0.006944	0.2091	0.08
11	5	1	9	2	1	0.006944	0.2091	0.08
12	5	1	2	2	1	0.006944	0.2091	0.08
13	5	1	2	2	1	0.006944	0.2091	0.08
14	5	1	2	2	1	0.006944	0.2091	0.08
15	5	1	2	2	1	0.006944	0.2091	0.08
16	5	1	2	2	1	0.006944	0.2091	0.08
17	5	1	2	2	1	0.006944	0.2091	0.08
18	5	1	2	2	1	0.006944	0.2091	0.08
1	6	1	7	2	1	0.006944	0.2091	0.08
2	6	1	7	2	1	0.006944	0.2091	0.08
3	6	1	7	2	1	0.006944	0.2091	0.08
4	6	1	7	2	1	0.006944	0.2091	0.08
5	6	1	7	2	1	0.006944	0.2091	0.08
6	6	1	7	2	1	0.006944	0.2091	0.08
7	6	1	7	2	1	0.006944	0.2091	0.08
8	6	1	9	2	1	0.006944	0.2091	0.08
9	6	1	9	2	1	0.006944	0.2091	0.08
10	6	1	9	2	1	0.006944	0.2091	0.08
11	6	1	9	2	1	0.006944	0.2091	0.08
12	6	1	2	2	1	0.006944	0.2091	0.08
13	6	1	2	2	1	0.006944	0.2091	0.08
14	6	1	2	2	1	0.006944	0.2091	0.08
15	6	1	2	2	1	0.006944	0.2091	0.08
16	6	1	2	2	1	0.006944	0.2091	0.08
17	6	1	2	2	1	0.006944	0.2091	0.08
18	6	1	2	2	1	0.006944	0.2091	0.08
1	7	1	8	2	1	0.006944	0.2091	0.08
2	7	1	8	2	1	0.006944	0.2091	0.08
3	7	1	8	2	1	0.006944	0.2091	0.08
4	7	1	8	2	1	0.006944	0.2091	0.08
5	7	1	8	2	1	0.006944	0.2091	0.08
6	7	1	8	2	1	0.006944	0.2091	0.08
7	7	1	8	2	1	0.006944	0.2091	0.08
8	7	1	9	2	1	0.006944	0.2091	0.08
9	7	1	9	2	1	0.006944	0.2091	0.08
10	7	1	9	2	1	0.006944	0.2091	0.08
11	7	1	9	2	1	0.006944	0.2091	0.08
12	7	1	1	2	1	0.006944	0.2091	0.08
13	7	1	1	2	1	0.006944	0.2091	0.08

14	7	1	1	2	1	0.006944	0.2091	0.08
15	7	1	1	2	1	0.006944	0.2091	0.08
16	7	1	1	2	1	0.006944	0.2091	0.08
17	7	1	1	2	1	0.006944	0.2091	0.08
18	7	1	1	2	1	0.006944	0.2091	0.08
1	8	1	8	2	1	0.006944	0.2091	0.08
2	8	1	8	2	1	0.006944	0.2091	0.08
3	8	1	8	2	1	0.006944	0.2091	0.08
4	8	1	8	2	1	0.006944	0.2091	0.08
5	8	1	8	2	1	0.006944	0.2091	0.08
6	8	1	8	2	1	0.006944	0.2091	0.08
7	8	1	8	2	1	0.006944	0.2091	0.08
8	8	1	9	2	1	0.006944	0.2091	0.08
9	8	1	9	2	1	0.006944	0.2091	0.08
10	8	1	9	2	1	0.006944	0.2091	0.08
11	8	1	9	2	1	0.006944	0.2091	0.08
12	8	1	1	2	1	0.006944	0.2091	0.08
13	8	1	1	2	1	0.006944	0.2091	0.08
14	8	1	1	2	1	0.006944	0.2091	0.08
15	8	1	1	2	1	0.006944	0.2091	0.08
16	8	1	1	2	1	0.006944	0.2091	0.08
17	8	1	1	2	1	0.006944	0.2091	0.08
18	8	1	1	2	1	0.006944	0.2091	0.08

Note: The brine pocket probability values in this file are not used in the current

FORTRAN PROGRAMS USED FOR BILINEARITY TEST

REL.T.FOR

C*****INPUT FILES:

C***** 2 = RELEASE SUMMARY TABLE (RELTABR1.DAT)

C*****OUTPUT FILES:

C***** 11 = RUN SUMMARY (CCGF_OUT)

C***** 12 = DOUBLED RELEASE TABLE (RELTABR1.NEW)

C***** 14 = NEW TABLES (CCGF_PRT)

IMPLICIT DOUBLE PRECISION (A-H, O-Z)

PARAMETER (MXY=20, MAXREC=100, MAXBH=100, MAXRES=50, MAXBIN=161,

1 MAXSPC=10, MAXSC=30, MAXOBS=100, MAXTH=10000,

2 MAXTIM=20, MAXBP=5, MAXACT=1000, MAXTC=200,

3 MAXVAR=100, MAXREG=5, NEQM=MXY*MXY, IBWM=3*MXY+1,

4 NUSED=3, NOTUSE=5, NTWO=2)

COMMON /INPUT1/ ISEED, IMBKCD, IOBS, ISPVAR, ITH, LHSVBP, NOBS,

1 NPF, NTH, NSPC, NREG, NBP, NPP

```

CHARACTER*80 FILBOR, FILINV, FILLHS, FILNOD, FILPAR, FILREG,
1          FILREL
COMMON /FILES/ FILBOR, FILINV, FILLHS, FILNOD, FILPAR, FILREG,
1          FILREL
CHARACTER*130 TITLEB, TITLEI, TITLEN, TITLEP, TITLER, TITLET
COMMON /TITLES/ TITLEB, TITLEI, TITLEN, TITLEP, TITLER, TITLET
LOGICAL GRDFLO, MINERD, PRTOBS, PRTHH
COMMON /INPUT0/ GRDFLO, MINERD, PRTOBS(MAXOBS), PRTHH(MAXTH)
COMMON /INPUT2/ SMT, VBT, TOTACT, ACTI, ACTS, TSMAX, TSLIM,
1          TEND, TENDBH, STPRST, DD1, DD2, DDTIME, PPP(3),
2          DM1, DM2, DMTIME, TOL, RTOL, RPTOL, BUFFRC,
3          GRAV, PI, ECULEB, ECASTI, PCULEB, PCASTI,
4          DIAMNA, DIAMXA, DIAMNB, DIAMXB, DMODA, DMODB,
5          PRMMNA, PRMMXA, PRMMNB, PRMMXB, PMODA, PMODB,
6          BRNDEN, BRNVIS
COMMON /CUT1/ NTCH, NTRH, NCH, NRH, NACH, NARH
COMMON /CUT2/ DBDIAM, ACH, ARH, FVCH, FVRH, HCH, HRH,
1          PCUT(MAXACT), TCH(MAXTIM), TRH(MAXTIM),
2          RCUT(MAXTIM,MAXACT), PWT(3,MAXREG)
COMMON /SPAL1/ NTSC, NTSLE0, NTSUE0,
1          NTSSE11, NTSDE11, NTSSE21, NTSDE21,
1          NTSSE12(MAXTIM), NTSDE12(MAXTIM),
2          NTSSE22(MAXTIM), NTSDE22(MAXTIM)
COMMON /SPAL2/ TSC(MAXTIM), CSA(MAXTIM),
1          TSLE0(MAXTIM), TSUE0(MAXTIM),
2          RSLE0(MAXTIM), RSUE0(MAXTIM),
3          TSSE1(MAXTIM,MAXTIM), RSSE1(MAXTIM,MAXTIM),
4          TSDE1(MAXTIM,MAXTIM), RSDE1(MAXTIM,MAXTIM),
5          TSSE2(MAXTIM,MAXTIM), RSSE2(MAXTIM,MAXTIM),
6          TSDE2(MAXTIM,MAXTIM), RSDE2(MAXTIM,MAXTIM)
COMMON /BLOW1/ NTBC, NTBLE0, NTBUE0,
1          NTBSE11, NTBDE11, NTBSE21, NTBDE21,
2          NTBSE12(MAXTIM), NTBDE12(MAXTIM),
3          NTBSE22(MAXTIM), NTBDE22(MAXTIM)
COMMON /BLOW2/ TBC(MAXTIM), CBE0(MAXTIM),
1          CBE1(MAXTIM), CBE2(MAXTIM),
2          TBLE0(MAXTIM), TBUE0(MAXTIM),
3          RBLE0(MAXTIM), RBUE0(MAXTIM),
4          TBSE1(MAXTIM,MAXTIM), RBSE1(MAXTIM,MAXTIM),
5          TBDE1(MAXTIM,MAXTIM), RBDE1(MAXTIM,MAXTIM),
6          TBSE2(MAXTIM,MAXTIM), RBSE2(MAXTIM,MAXTIM),
7          TBDE2(MAXTIM,MAXTIM), RBDE2(MAXTIM,MAXTIM)

```

```

CHARACTER LABSET(MAXREC,NUSED,NTWO)*48
CHARACTER LNOUSE(NOTUSE)*38, LINE3(NUSED)*30
CHARACTER SLABEL(MAXREC,NUSED,NTWO)*55
CHARACTER BLABEL(MAXREC,NUSED,NTWO)*55
COMMON /LABEL1/ BLABEL, LABSET, LINE3, LNOUSE
COMMON /LABEL2/ SLABEL

C
C*****OPEN RELEASE SUMMARY TABLE FILE
      OPEN( 2,FILE='RELTABR1.DAT', RECL=100, STATUS='UNKNOWN')
C      OPEN( 2,FILE='RELTABR1.OUT', RECL=100, STATUS='UNKNOWN')
C*****OPEN RELEASE SUMMARY TABLE FILE
      OPEN(12,FILE='RELTABR1.NEW', RECL=100, STATUS='UNKNOWN')

C
C*****OPEN PRINT FILE
      OPEN (11, FILE='CCGF_PRT', RECL=200, STATUS='UNKNOWN')
C*****OPEN FILE FOR STORING NEW TABLES
      OPEN (14, FILE='CCGF_OUT', RECL=1000, STATUS='UNKNOWN')
      NOBS=100
      ACTI=1.E32
      TEND=1.E-32
C*****OPEN AND READ INPUT DATA FILES
      CALL INPUT
C*****LOOP OVER OBSERVATIONS
      DO 5000 IOBS=1,NOBS
C*****READ RELEASE TABLES
      CALL READR
C *****PRINT NUMBERS READ
      NINE=9
      LAST=570
      IF(IOBS.EQ.NOBS .OR. IOBS.EQ.1) THEN
        WRITE(14,*) 'SPALLINGS, IOBS=',IOBS
        WRITE(14,914) (TSLE0(IT),IT=1,NINE)
        WRITE(14,914) (RSLE0(IT),IT=1,NINE)
        WRITE(14,914) (TSUE0(IT),IT=1,NINE)
        WRITE(14,914) (RSUE0(IT),IT=1,NINE)
        DO 205 IT2=1,NINE
          WRITE(14,914) (RSSE1(IT2,IT1),IT1=1,NINE)
          WRITE(14,914) (RSDE2(IT2,IT1),IT1=1,NINE)
205      CONTINUE
        WRITE(14,*) 'BLOWOUT, IOBS=',IOBS
        WRITE(14,914) (RBLE0(IT),IT=1,NINE)
        WRITE(14,914) (RBUE0(IT),IT=1,NINE)

```

```

DO 210 IT2=1,NINE
    WRITE(14,914) (RBSE1(IT2,IT1),IT1=1,NINE)
    WRITE(14,914) (RBDE2(IT2,IT1),IT1=1,NINE)
210 CONTINUE
    WRITE(14,*) 'CUTTINGS, IOBS=',IOBS
    WRITE(14,913) 'STREAM CDF ',(TCH(IT),IT=1,NINE)
913 FORMAT(A12,9F7.0)
    DO 200 ISTREAM=1,LAST
        WRITE(14,912) ISTREAM,PCUT(ISTREAM),
2                (RCUT(IT,ISTREAM),IT=1,NINE)
912 FORMAT(I4,F8.6,9F7.3)
200 CONTINUE
914 FORMAT(9E9.1)
    ENDIF
    CALL DOUBLE
5000 CONTINUE
C
    STOP
    END
C
C.....^.....
    SUBROUTINE RDREL (ERR)
C*****READ SUMMARY RELEASE TABLES FILE HEADERS
    IMPLICIT DOUBLE PRECISION (A-H, O-Z)
    PARAMETER (MXY=20, MAXREC=100, MAXBH=100, MAXRES=50, MAXBIN=161,
1            MAXSPC=10, MAXSC=30, MAXOBS=100, MAXTH=10000,
2            MAXTIM=20, MAXBP=5, MAXACT=1000, MAXTC=200,
3            MAXVAR=100, MAXREG=5, NEQM=MXY*MXY, IBWM=3*MXY+1,
4            NUSED=3, NOTUSE=5, NTWO=2)
    COMMON /INPUT1/ ISEED, IMBCKD, IOBS, ISPVAR, ITH, LHSVBP, NOBS,
1            NPF, NTH, NSPC, NREG, NBP, NPP
    CHARACTER*130 TITLEB, TITLEI, TITLEN, TITLEP, TITLER, TITLET
    COMMON /TITLES/ TITLEB, TITLEI, TITLEN, TITLEP, TITLER, TITLET
    CHARACTER*80 FILBOR, FILINV, FILLHS, FILNOD, FILPAR, FILREG,
1            FILREL
    COMMON /FILES/ FILBOR, FILINV, FILLHS, FILNOD, FILPAR, FILREG,
1            FILREL
    LOGICAL ERR
    CHARACTER LABSET(MAXREC,NUSED,NTWO)*48
    CHARACTER LNOUSE(NOTUSE)*38, LINE3(NUSED)*30
    CHARACTER SLABEL(MAXREC,NUSED,NTWO)*55
    CHARACTER BLABEL(MAXREC,NUSED,NTWO)*55

```

```

COMMON /LABEL1/ BLABEL, LABSET, LINE3, LNOUSE
COMMON /LABEL2/ SLABEL

C
C
C*****READ RELEASE SUMMARY TABLE TITLE
      READ(2,1001,ERR=9200,END=9300) TITLET
      LINE3(1)=TITLET
C*****LABEL SECOND TITLE RECORD FOR RELEASE SUMMARY TABLE
      READ(2,911,ERR=9200,END=9300) LINE3(2)
911  FORMAT(A30)
C*****READ NUMBER OF OBSERVATIONS ON RELEASE SUMMARY TABLE
      READ(2,912,ERR=9200,END=9300) NOBST,LINE3(3)
912  FORMAT(I10,A30)
C*****CHECK NUMBER OF OBSERVATIONS ON RELEASE SUMMARY TABLE FOR AT LEAST
C*****AS MANY OBSERVATIONS SPECIFIED ON RUN CONTROL PARAMETERS FILE
      IF (NOBS .GT. NOBST) THEN
C*****NOT ENOUGH OBSERVATIONS ON RELEASE SUMMARY TABLE FILE
      WRITE(11,*) '>>>>FEWER OBSERVATIONS ON RELEASE SUMMARY ',
1      'TABLE FILE (' , NOBST, ')'
      WRITE(11,*) '>>>>THAN ON RUN CONTROL PARAMETERS FILE (' ,
1      NOBS, ')'
      ERR=.TRUE.
      ENDIF
      RETURN
C*****ERROR OPENING RELEASE SUMMARY TABLES FILE
C 9100 CONTINUE
C      WRITE(11,*) '>>>>ERROR OPENING RELEASE SUMMARY TABLES FILE'
C      ERR=.TRUE.
C      RETURN
C*****I/O ERROR READING HEADER RECORDS FROM RELEASE SUMMARY TABLES FILE
9200 CONTINUE
      WRITE(11,*) '>>>>I/O ERROR READING HEADER RECORDS FROM ',
1      'RELEASE SUMMARY TABLES FILE'
      ERR=.TRUE.
      RETURN
C*****PREMATURE EOF ENCOUNTERED READING HEADER RECORDS FROM RELEASE SUMMARY
C*****TABLES FILE
9300 CONTINUE
      WRITE(11,*) '>>>>PREMATURE EOF ENCOUNTERED READING ',
1      'RELEASE SUMMARY TABLES FILE'
      ERR=.TRUE.
      RETURN

```

```

C*****FORMAT STATEMENTS
1001 FORMAT(A)
      END
C
C.....^.....
      SUBROUTINE INPUT
C*****READ NODE DEFINITION AND REDEFINITION DESCRIPTIONS
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      PARAMETER (MXY=20, MAXREC=100, MAXBH=100, MAXRES=50, MAXBIN=161,
1          MAXSPC=10, MAXSC=30, MAXOBS=100, MAXTH=10000,
2          MAXTIM=20, MAXBP=5, MAXACT=1000, MAXTC=200,
3          MAXVAR=100, MAXREG=5, NEQM=MXY*MXY, IBWM=3*MXY+1)
      COMMON /INPUT1/ ISEED, IMBKCD, IOBS, ISPVAR, ITH, LHSVBP, NOBS,
1          NPF, NTH, NSPC, NREG, NBP, NPP
      CHARACTER*130 TITLEB, TITLEI, TITLEN, TITLEP, TITLER, TITLET
      COMMON /TITLES/ TITLEB, TITLEI, TITLEN, TITLEP, TITLER, TITLET
      CHARACTER*80 FILBOR, FILINV, FILLHS, FILNOD, FILPAR, FILREG,
1          FILREL
      COMMON /FILES/ FILBOR, FILINV, FILLHS, FILNOD, FILPAR, FILREG,
1          FILREL
      LOGICAL ERR
C*****INITIALIZE ERROR FLAG
      ERR=.FALSE.
C*****READ RELEASE SUMMARY TABLES FILE HEADERS
      CALL RDREL (ERR)
      IF (ERR) THEN
          WRITE(6,*) '>>>>ERROR(1) ENCOUNTERED, EXECUTION TERMINATED'
          STOP
      ENDIF
      END
C
C.....^.....
      SUBROUTINE RDCUT
C*****READ CUTTINGS RELEASE TABLES
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      PARAMETER (MXY=20, MAXREC=100, MAXBH=100, MAXRES=50, MAXBIN=161,
1          MAXSPC=10, MAXSC=30, MAXOBS=100, MAXTH=10000,
2          MAXTIM=20, MAXBP=5, MAXACT=1000, MAXTC=200,
3          MAXVAR=100, MAXREG=5, NEQM=MXY*MXY, IBWM=3*MXY+1,
4          NUSED=3, NOTUSE=5, NTWO=2)
      LOGICAL GRDFLO, MINERD, PRTOBS, PRTH
      COMMON /INPUT0/ GRDFLO, MINERD, PRTOBS(MAXOBS), PRTH(MAXTH)

```

```

COMMON /INPUT1/ ISEED, IMCKD, IOBS, ISPVAR, ITH, LHSVBP, NOBS,
1          NPF, NTH, NSPC, NREG, NBP, NPP
COMMON /INPUT2/ SMT, VBT, TOTACT, ACTI, ACTS, TSMAX, TSLIM,
1          TEND, TENDBH, STPRST, DD1, DD2, DDTIME, PPP(3),
2          DM1, DM2, DMTIME, TOL, RTOL, RPTOL, BUFFRC,
3          GRAV, PI, ECULEB, ECASTI, PCULEB, PCASTI,
4          DIAMNA, DIAMXA, DIAMNB, DIAMXB, DMODA, DMODB,
5          PRMMNA, PRMMXA, PRMMNB, PRMMXB, PMODA, PMODB,
6          BRNDEN, BRNVIS
COMMON /CUT1/ NTCH, NTRH, NCH, NRH, NACH, NARH
COMMON /CUT2/ DBDIAM, ACH, ARH, FVCH, FVRH, HCH, HRH,
1          PCUT(MAXACT), TCH(MAXTIM), TRH(MAXTIM),
2          RCUT(MAXTIM,MAXACT), PWT(3,MAXREG)
CHARACTER LABSET(MAXREC,NUSED,NTWO)*48
CHARACTER LNOUSE(NOTUSE)*38, LINE3(NUSED)*30
CHARACTER SLABEL(MAXREC,NUSED,NTWO)*55
CHARACTER BLABEL(MAXREC,NUSED,NTWO)*55
COMMON /LABEL1/ BLABEL, LABSET, LINE3, LNOUSE
COMMON /LABEL2/ SLABEL

C
C
C*****READ FLAGS ON CUTTINGS RELEASES TITLE RECORD
      READ(2,911,ERR=9200,END=9300) IOBST, IFLG, LABSET(IOBS,1,1)
911  FORMAT(2I10,A48)
C*****VALIDATE OBSERVATION INDEX
C      WRITE(*,*) IOBST,IFLG,IOBS
      IF (IOBST .NE. IOBS) THEN
C*****INVALID OBSERVATION INDEX VALUE
          WRITE(11,*) '>>>>INVALID OBSERVATION INDEX VALUE FOR ',
1          'CUTTINGS RELEASE TABLES'
          WRITE(6,*) '>>>>ERROR(2) ENCOUNTERED, EXECUTION TERMINATED'
          STOP
      ENDIF
C*****READ NUMBER OF TIMES, NUMBER OF WASTE TYPES, WASTE AREA,
C*****WASTE HEIGHT, VOLUME FRACTION, AND DRILL BIT DIAMETER FOR CH WASTE
      READ(2,*,ERR=9200,END=9300) NTCH, NCH, ACH, HCH, FVCH, DBDIAM
C*****READ NUMBER OF TIMES, NUMBER OF WASTE TYPES, WASTE AREA,
C*****WASTE HEIGHT, AND VOLUME FRACTION FOR RH WASTE
      READ(2,*,ERR=9200,END=9300) NTRH, NRH, ARH, HRH, FVRH
C      WRITE(*,*) NCH,NRH,NTCH,NTRH
C*****VALIDATE TIME DIMENSION
      IF ((NTCH .GT. MAXTIM) .OR. (NTRH .GT. MAXTIM)) THEN

```

```

        WRITE(11,*) '>>>>INCREASE PARAMETER MAXTIM TO AT LEAST ',
1          MAX(NTCH,NTRH)
        WRITE(6,*) '>>>>ERROR(3) ENCOUNTERED, EXECUTION TERMINATED'
        STOP
    ENDIF
C*****VALIDATE TOTAL NUMBER OF CH AND RH WASTE TYPES
    IF (NCH+NRH .GT. MAXACT) THEN
        WRITE(11,*) '>>>>INCREASE PARAMETER MAXACT TO AT LEAST ',
1          NCH+NRH
        WRITE(6,*) '>>>>ERROR(4) ENCOUNTERED, EXECUTION TERMINATED'
        STOP
    ENDIF
C*****CHECK FLAG FOR READING RELEASE TABLES
    IF (IFLG .EQ. 0) RETURN
C*****READ PROBABILITIES ASSOCIATED WITH EACH ACTIVITY LEVEL FOR
C*****CH AND RH WASTES
        READ(2,*,ERR=9200,END=9300) (PCUT(ICH),ICH=1,NCH),
1          (PCUT(NCH+IRH),IRH=1,NRH)
C*****WRITE TIMES FOR ACTIVITY LEVELS FOR CH WASTE
        READ(2,*,ERR=9200,END=9300) (TCH(IT),IT=1,NTCH)
C*****READ TIMES FOR ACTIVITY LEVELS FOR RH WASTE
        READ(2,*,ERR=9200,END=9300) (TRH(IT),IT=1,NTRH)
C*****READ RELEASES FOR ALL TIMES FOR CH AND RH WASTE
        READ(2,*,ERR=9200,END=9300) ((RCUT(IT,ICH),IT=1,NTCH),ICH=1,NCH),
1          ((RCUT(IT,NCH+IRH),IT=1,NTRH),IRH=1,NRH)
C*****CHECK FOR MORE THAN ONE TYPE OF CH WASTE
    IF (NCH .GT. 1) THEN
C*****LOOP OVER TYPE OF CH WASTE
        DO 1000 ICH=2,NCH
C*****CONVERT PROBABILITIES FOR EACH ACTIVITY LEVEL TO CUMULATIVE PROB
            PCUT(ICH)=PCUT(ICH-1) + PCUT(ICH)
1000    CONTINUE
        ENDIF
C*****CHECK FOR MORE THAN ONE TYPE OF RH WASTE
    IF (NRH .GT. 1) THEN
C*****LOOP OVER TYPE OF RH WASTE
        DO 2000 IRH=NCH+2,NCH+NRH
C*****CONVERT PROBABILITIES FOR EACH ACTIVITY LEVEL TO CUMULATIVE PROB
            PCUT(IRH)=PCUT(IRH-1) + PCUT(IRH)
2000    CONTINUE
        ENDIF
C*****VALIDATE TIME RANGE FOR CUTTINGS CH RELEASES

```

```

        IF ((TCH(1) .GT. ACTI) .OR. (TCH(NTCH) .LT. TEND)) THEN
            WRITE(11,*) '>>>>CUTTINGS CH RELEASE TABLE DOES NOT SPAN ',
1            'POTENTIAL INTRUSION'
            WRITE(11,*) '>>>>TIMES (', ACTI, ' TO ', TEND, ' YR)'
            WRITE(6,*) '>>>>ERROR(5) ENCOUNTERED, EXECUTION TERMINATED'
            STOP
        ENDIF
C*****VALIDATE TIME RANGE FOR CUTTINGS RH RELEASES
        IF ((TRH(1) .GT. ACTI) .OR. (TRH(NTRH) .LT. TEND)) THEN
            WRITE(11,*) '>>>>CUTTINGS RH RELEASE TABLE DOES NOT SPAN ',
1            'POTENTIAL INTRUSION'
            WRITE(11,*) '>>>>TIMES (', ACTI, ' TO ', TEND, ' YR)'
            WRITE(6,*) '>>>>ERROR(6) ENCOUNTERED, EXECUTION TERMINATED'
            STOP
        ENDIF
        RETURN
9200 CONTINUE
C*****I/O ERROR WHILE READING CUTTINGS RELEASE TABLES
        WRITE(11,*) '>>>>I/O ERROR WHILE READING CUTTINGS RELEASE TABLES'
        WRITE(6,*) '>>>>ERROR(7) ENCOUNTERED, EXECUTION TERMINATED'
        STOP
9300 CONTINUE
C*****PREMATURE EOF ENCOUNTERED READING CUTTINGS RELEASE TABLES
        WRITE(11,*) '>>>>PREMATURE EOF ENCOUNTERED READING ',
1            'CUTTINGS RELEASE TABLES'
        WRITE(6,*) '>>>>ERROR(8) ENCOUNTERED, EXECUTION TERMINATED'
        STOP
        END
C
C.....^.....
        SUBROUTINE RDSPL
C*****READ SPALLINGS RELEASE TABLES
        IMPLICIT DOUBLE PRECISION (A-H, O-Z)
        PARAMETER (MXY=20, MAXREC=100, MAXBH=100, MAXRES=50, MAXBIN=161,
1            MAXSPC=10, MAXSC=30, MAXOBS=100, MAXTH=10000,
2            MAXTIM=20, MAXBP=5, MAXACT=1000, MAXTC=200,
3            MAXVAR=100, MAXREG=5, NEQM=MXY*MXY, IBWM=3*MXY+1,
4            NUSED=3, NOTUSE=5, NTWO=2)
        LOGICAL GRDFLO, MINERD, PRTOBS, PRTH
        COMMON /INPUT0/ GRDFLO, MINERD, PRTOBS(MAXOBS), PRTH(MAXTH)
        COMMON /INPUT1/ ISEED, IMBKD, IOBS, ISPVAR, ITH, LHSVBP, NOBS,
1            NPF, NTH, NSPC, NREG, NBP, NPP

```

```

COMMON /INPUT2/ SMT, VBT, TOTACT, ACTI, ACTS, TSMAX, TSLIM,
1          TEND, TENDBH, STPRST, DD1, DD2, DDTIME, PPP(3),
2          DM1, DM2, DMTIME, TOL, RTOL, RPTOL, BUFFRC,
3          GRAV, PI, ECULEB, ECASTI, PCULEB, PCASTI,
4          DIAMNA, DIAMXA, DIAMNB, DIAMXB, DMODA, DMODB,
5          PRMMNA, PRMMXA, PRMMNB, PRMMXB, PMODA, PMODB,
6          BRNDEN, BRNVIS
COMMON /SPAL1/ NTSC, NTSLE0, NTSUE0,
1          NTSSE11, NTSDE11, NTSSE21, NTSDE21,
1          NTSSE12(MAXTIM), NTSDE12(MAXTIM),
2          NTSSE22(MAXTIM), NTSDE22(MAXTIM)
COMMON /SPAL2/ TSC(MAXTIM), CSA(MAXTIM),
1          TSLE0(MAXTIM), TSUE0(MAXTIM),
2          RSLE0(MAXTIM), RSUE0(MAXTIM),
3          TSSE1(MAXTIM,MAXTIM), RSSE1(MAXTIM,MAXTIM),
4          TSDE1(MAXTIM,MAXTIM), RSDE1(MAXTIM,MAXTIM),
5          TSSE2(MAXTIM,MAXTIM), RSSE2(MAXTIM,MAXTIM),
6          TSDE2(MAXTIM,MAXTIM), RSDE2(MAXTIM,MAXTIM)
CHARACTER LABSET(MAXREC,NUSED,NTWO)*48
CHARACTER LNOUSE(NOTUSE)*38, LINE3(NUSED)*30
CHARACTER SLABEL(MAXREC,NUSED,NTWO)*55
CHARACTER BLABEL(MAXREC,NUSED,NTWO)*55
COMMON /LABEL1/ BLABEL, LABSET, LINE3, LNOUSE
COMMON /LABEL2/ SLABEL

C
C
C*****READ FLAGS ON SPALLINGS RELEASES TITLE RECORD
      READ(2,911,ERR=9200,END=9300) IOBST, IFLG, LABSET(IOBS,2,1)
911  FORMAT(2I10,A48)
C      WRITE(*,*) IOBST,IFLG,IOBS
C*****VALIDATE OBSERVATION INDEX
      IF (IOBST .NE. IOBS) THEN
C*****INVALID OBSERVATION INDEX VALUE
          WRITE(11,*) '>>>>INVALID OBSERVATION INDEX VALUE FOR ',
1          'SPALLINGS RELEASE TABLES'
          WRITE(6,*) '>>>>ERROR(9) ENCOUNTERED, EXECUTION TERMINATED'
          STOP
      ENDIF
C*****CHECK FLAG FOR READING RELEASE TABLES
      IF (IFLG .EQ. 0) RETURN
C*****LABEL SPALLINGS HEADER RECORD FOR CONCENTRATIONS
      READ(2,912,ERR=9200,END=9300) LABSET(IOBS,2,2)

```

```

912  FORMAT(A48)
C*****READ CONCENTRATION VALUES FOR SPALLINGS RELEASES
      READ(2,*,ERR=9200,END=9300) NTSC, (TSC(IT),IT=1,NTSC),
1                                     (CSA(IT),IT=1,NTSC)
C*****LABEL SPALLINGS HEADER RECORD FOR UNDISTURBED CONDITIONS (LOWER PANELS)
      READ(2,913,ERR=9200,END=9300) SLABEL(IOBS,1,1)
913  FORMAT(A55)
C*****READ SPALLINGS RELEASES FOR UNDISTURBED CONDITIONS (LOWER PANELS)
      READ(2,*,ERR=9200,END=9300) NTSLE0, (TSLE0(IT),IT=1,NTSLE0),
1                                     (RSLE0(IT),IT=1,NTSLE0)
C*****LABEL SPALLINGS HEADER RECORD FOR UNDISTURBED CONDITIONS (UPPER PANELS)
      READ(2,913,ERR=9200,END=9300) SLABEL(IOBS,1,2)
C*****READ SPALLINGS RELEASES FOR UNDISTURBED CONDITIONS (UPPER PANELS)
      READ(2,*,ERR=9200,END=9300) NTSUE0, (TSUE0(IT),IT=1,NTSUE0),
1                                     (RSUE0(IT),IT=1,NTSUE0)
C*****LABEL SPALLINGS HEADER RECORD FOR E1 INTRUSIONS (SAME PANEL)
      READ(2,913,ERR=9200,END=9300) SLABEL(IOBS,2,1)
C*****READ SPALLINGS RELEASES FOR E1 INTRUSIONS (SAME PANEL)
      READ(2,*,ERR=9200,END=9300) NTSSE11, (NTSSE12(IT1),
1          (TSSE1(IT2,IT1),IT2=1,NTSSE12(IT1)),
2          (RSSE1(IT2,IT1),IT2=1,NTSSE12(IT1)), IT1=1,NTSSE11)
C*****LABEL SPALLINGS HEADER RECORD FOR E1 INTRUSIONS (DIFFERENT PANEL)
      READ(2,913,ERR=9200,END=9300) SLABEL(IOBS,2,2)
C*****READ SPALLINGS RELEASES FOR E1 INTRUSIONS (DIFFERENT PANEL)
      READ(2,*,ERR=9200,END=9300) NTSDE11, (NTSDE12(IT1),
1          (TSDE1(IT2,IT1),IT2=1,NTSDE12(IT1)),
2          (RSDE1(IT2,IT1),IT2=1,NTSDE12(IT1)), IT1=1,NTSDE11)
C*****LABEL SPALLINGS HEADER RECORD FOR E2 INTRUSIONS (SAME PANEL)
      READ(2,913,ERR=9200,END=9300) SLABEL(IOBS,3,1)
C*****READ SPALLINGS RELEASES FOR E2 INTRUSIONS (SAME PANEL)
      READ(2,*,ERR=9200,END=9300) NTSSE21, (NTSSE22(IT1),
1          (TSSE2(IT2,IT1),IT2=1,NTSSE22(IT1)),
2          (RSSE2(IT2,IT1),IT2=1,NTSSE22(IT1)), IT1=1,NTSSE21)
C*****LABEL SPALLINGS HEADER RECORD FOR E2 INTRUSIONS (DIFFERENT PANEL)
      READ(2,913,ERR=9200,END=9300) SLABEL(IOBS,3,2)
C*****READ SPALLINGS RELEASES FOR E2 INTRUSIONS (DIFFERENT PANEL)
      READ(2,*,ERR=9200,END=9300) NTSDE21, (NTSDE22(IT1),
1          (TSDE2(IT2,IT1),IT2=1,NTSDE22(IT1)),
2          (RSDE2(IT2,IT1),IT2=1,NTSDE22(IT1)), IT1=1,NTSDE21)
C*****VALIDATE TIME RANGE FOR SPALLINGS RELEASES
      IF ((TSC(1) .GT. ACTI) .OR.
1      (TSLE0(1) .GT. ACTI) .OR. (TSUE0(1) .GT. ACTI) .OR.

```

```

2   (TSSE1(1,1) .GT. ACTI) .OR. (TSDE1(1,1) .GT. ACTI) .OR.
3   (TSSE2(1,1) .GT. ACTI) .OR. (TSDE2(1,1) .GT. ACTI)) THEN
WRITE(11,*) '>>>>SPALLINGS RELEASE TABLE DOES NOT SPAN ',
1   'POTENTIAL INTRUSION TIMES'
WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
WRITE(6,*) '>>>>ERROR(A) ENCOUNTERED, EXECUTION TERMINATED'
STOP
ENDIF
C*****DETERMINE MAXIMUM COUNTER FOR SPALLINGS RELEASE TABLES
NTSMAX=MAX (NTSC, NTSLE0, NTSUE0, NTSSE11, NTSDE11, NTSSE21,
1   NTSDE21)
C*****VALIDATE TIME RANGE FOR SPALLINGS RELEASES
IF ((TSC(NTSC) .LT. TEND) .OR. (TSLE0(NTSLE0) .LT. TEND) .OR.
1   (TSUE0(NTSUE0) .LT. TEND)) THEN
WRITE(11,*) '>>>>SPALLINGS RELEASE TABLE DOES NOT SPAN ',
1   'POTENTIAL INTRUSION TIMES'
WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
WRITE(6,*) '>>>>ERROR(B) ENCOUNTERED, EXECUTION TERMINATED'
STOP
ENDIF
DO 2100 IT1=1,NTSSE11
NTSMAX=MAX (NTSMAX, NTSSE12(IT1))
C*****VALIDATE TIME RANGE FOR SPALLINGS RELEASES
IF (TSSE1(NTSSE12(IT1),IT1) .LT. TEND) THEN
WRITE(11,*) '>>>>SPALLINGS RELEASE TABLE DOES NOT SPAN ',
1   'POTENTIAL INTRUSION TIMES'
WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
WRITE(6,*) '>>>>ERROR(C) ENCOUNTERED, EXECUTION TERMINATED'
STOP
ENDIF
2100 CONTINUE
DO 2150 IT1=1,NTSDE11
NTSMAX=MAX (NTSMAX, NTSDE12(IT1))
C*****VALIDATE TIME RANGE FOR SPALLINGS RELEASES
IF (TSDE1(NTSDE12(IT1),IT1) .LT. TEND) THEN
WRITE(11,*) '>>>>SPALLINGS RELEASE TABLE DOES NOT SPAN ',
1   'POTENTIAL INTRUSION TIMES'
WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
WRITE(6,*) '>>>>ERROR(D) ENCOUNTERED, EXECUTION TERMINATED'
STOP
ENDIF
2150 CONTINUE

```

```

DO 2200 IT1=1,NTSSE21
    NTSMAX=MAX (NTSMAX, NTSSE22(IT1))
C*****VALIDATE TIME RANGE FOR SPALLINGS RELEASES
    IF (TSSE2(NTSSE22(IT1),IT1) .LT. TEND) THEN
        WRITE(11,*) '>>>>SPALLINGS RELEASE TABLE DOES NOT SPAN ',
1          'POTENTIAL INTRUSION TIMES'
        WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
        WRITE(6,*) '>>>>ERROR(E) ENCOUNTERED, EXECUTION TERMINATED'
        STOP
    ENDIF
2200 CONTINUE
DO 2250 IT1=1,NTSDE21
    NTSMAX=MAX (NTSMAX, NTSDE22(IT1))
C*****VALIDATE TIME RANGE FOR SPALLINGS RELEASES
    IF (TSDE2(NTSDE22(IT1),IT1) .LT. TEND) THEN
        WRITE(11,*) '>>>>SPALLINGS RELEASE TABLE DOES NOT SPAN ',
1          'POTENTIAL INTRUSION TIMES'
        WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
        WRITE(6,*) '>>>>ERROR(F) ENCOUNTERED, EXECUTION TERMINATED'
        STOP
    ENDIF
2250 CONTINUE
C*****VALIDATE MAXIMUM COUNTER FOR SPALLINGS RELEASE TABLES
    IF (NTSMAX .GT. MAXTIM) THEN
        WRITE(11,*) '>>>>INCREASE VALUE OF PARAMETER MAXTIM TO AT ',
1          'LEAST ', NTSMAX
        WRITE(6,*) '>>>>ERROR(G) ENCOUNTERED, EXECUTION TERMINATED'
        STOP
    ENDIF
C*****VALIDATE 1ST INTRUSION TIMES (INCREASING ORDER), UNDISTURBED CONDITIONS
DO 2300 IT=2,NTSLE0
    IF (TSLE0(IT) .LE. TSLE0(IT-1)) THEN
        WRITE(11,*) '>>>>SPALLINGS RELEASE TIMES FOR UNDISTURBED ',
1          'CONDITIONS NOT IN INCREASING ORDER'
        WRITE(6,*) '>>>>ERROR(H) ENCOUNTERED, EXECUTION TERMINATED'
        STOP
    ENDIF
2300 CONTINUE
DO 2350 IT=2,NTSUE0
    IF (TSUE0(IT) .LE. TSUE0(IT-1)) THEN
        WRITE(11,*) '>>>>SPALLINGS RELEASE TIMES FOR UNDISTURBED ',
1          'CONDITIONS NOT IN INCREASING ORDER'

```

```

        WRITE(6,*) '>>>>ERROR(I) ENCOUNTERED, EXECUTION TERMINATED'
        STOP
    ENDIF
2350 CONTINUE
C*****VALIDATE 1ST INTRUSION TIMES (INCREASING ORDER), E1 INTRUSIONS
    DO 2400 IT1=2,NTSSE11
        IF (TSSE1(1,IT1) .LE. TSSE1(1,IT1-1)) THEN
            WRITE(11,*) '>>>>SPALLINGS RELEASE TIMES FOR E1 ',
1                'INTRUSIONS NOT IN INCREASING ORDER'
            WRITE(6,*) '>>>>ERROR(J) ENCOUNTERED, EXECUTION TERMINATED'
            STOP
        ENDIF
2400 CONTINUE
    DO 2450 IT1=2,NTSDE11
        IF (TSDE1(1,IT1) .LE. TSDE1(1,IT1-1)) THEN
            WRITE(11,*) '>>>>SPALLINGS RELEASE TIMES FOR E1 ',
1                'INTRUSIONS NOT IN INCREASING ORDER'
            WRITE(6,*) '>>>>ERROR(K) ENCOUNTERED, EXECUTION TERMINATED'
            STOP
        ENDIF
2450 CONTINUE
C*****VALIDATE 2ND INTRUSION TIMES (INCREASING ORDER), E1 INTRUSIONS
    DO 2600 IT1=1,NTSSE11
        DO 2500 IT2=2,NTSSE12(IT1)
            IF (TSSE1(IT2,IT1) .LE. TSSE1(IT2-1,IT1)) THEN
                WRITE(11,*) '>>>>SPALLINGS RELEASE TIMES FOR E1 ',
1                    'INTRUSIONS NOT IN INCREASING ORDER'
                WRITE(6,*) '>>>>ERROR(L) ENCOUNTERED, EXECUTION ',
1                    'TERMINATED'
                STOP
            ENDIF
2500 CONTINUE
2600 CONTINUE
    DO 2650 IT1=1,NTSDE11
        DO 2550 IT2=2,NTSDE12(IT1)
            IF (TSDE1(IT2,IT1) .LE. TSDE1(IT2-1,IT1)) THEN
                WRITE(11,*) '>>>>SPALLINGS RELEASE TIMES FOR E1 ',
1                    'INTRUSIONS NOT IN INCREASING ORDER'
                WRITE(6,*) '>>>>ERROR(M) ENCOUNTERED, EXECUTION ',
1                    'TERMINATED'
                STOP
            ENDIF
2550 CONTINUE
2650 CONTINUE

```

```

2550 CONTINUE
2650 CONTINUE
C*****VALIDATE 1ST INTRUSION TIMES (INCREASING ORDER), E2 INTRUSIONS
DO 2700 IT1=2,NTSSE21
  IF (TSSE2(1,IT1) .LE. TSSE2(1,IT1-1)) THEN
    WRITE(11,*) '>>>>SPALLINGS RELEASE TIMES FOR E2 ',
1      'INTRUSIONS NOT IN INCREASING ORDER'
    WRITE(6,*) '>>>>ERROR(N) ENCOUNTERED, EXECUTION TERMINATED'
    STOP
  ENDIF
2700 CONTINUE
DO 2750 IT1=2,NTSDE21
  IF (TSDE2(1,IT1) .LE. TSDE2(1,IT1-1)) THEN
    WRITE(11,*) '>>>>SPALLINGS RELEASE TIMES FOR E2 ',
1      'INTRUSIONS NOT IN INCREASING ORDER'
    WRITE(6,*) '>>>>ERROR(L) ENCOUNTERED, EXECUTION TERMINATED'
    STOP
  ENDIF
2750 CONTINUE
C*****VALIDATE 2ND INTRUSION TIMES (INCREASING ORDER), E2 INTRUSIONS
DO 2900 IT1=1,NTSSE21
  DO 2800 IT2=2,NTSSE22(IT1)
    IF (TSSE2(IT2,IT1) .LE. TSSE2(IT2-1,IT1)) THEN
      WRITE(11,*) '>>>>SPALLINGS RELEASE TIMES FOR E2 ',
1      'INTRUSIONS NOT IN INCREASING ORDER'
      WRITE(6,*) '>>>>ERROR(M) ENCOUNTERED, EXECUTION ',
1      'TERMINATED'
      STOP
    ENDIF
2800 CONTINUE
2900 CONTINUE
DO 2950 IT1=1,NTSDE21
  DO 2850 IT2=2,NTSDE22(IT1)
    IF (TSDE2(IT2,IT1) .LE. TSDE2(IT2-1,IT1)) THEN
      WRITE(11,*) '>>>>SPALLINGS RELEASE TIMES FOR E2 ',
1      'INTRUSIONS NOT IN INCREASING ORDER'
      WRITE(6,*) '>>>>ERROR(N) ENCOUNTERED, EXECUTION ',
1      'TERMINATED'
      STOP
    ENDIF
2850 CONTINUE
2950 CONTINUE

```

```

RETURN
C*****I/O ERROR WHILE READING SPALLINGS RELEASE TABLES
9200 CONTINUE
WRITE(11,*) '>>>>I/O ERROR WHILE READING SPALLINGS RELEASE ',
1      'TABLES'
WRITE(6,*) '>>>>ERROR(O) ENCOUNTERED, EXECUTION TERMINATED'
STOP
C*****PREMATURE EOF ENCOUNTERED READING SPALLINGS RELEASE TABLES
9300 CONTINUE
WRITE(11,*) '>>>>PREMATURE EOF ENCOUNTERED READING ',
1      'SPALLINGS RELEASE TABLES'
WRITE(6,*) '>>>>ERROR(P) ENCOUNTERED, EXECUTION TERMINATED'
STOP
END
C
C.....^.....
SUBROUTINE RDBLW
C*****READ BLOWOUT RELEASE TABLES
IMPLICIT DOUBLE PRECISION (A-H, O-Z)
PARAMETER (MXY=20, MAXREC=100, MAXBH=100, MAXRES=50, MAXBIN=161,
1      MAXSPC=10, MAXSC=30, MAXOBS=100, MAXTH=10000,
2      MAXTIM=20, MAXBP=5, MAXACT=1000, MAXTC=200,
3      MAXVAR=100, MAXREG=5, NEQM=MXY*MXY, IBWM=3*MXY+1,
4      NUSED=3, NOTUSE=5, NTWO=2)
LOGICAL GRDFLO, MINERD, PRTOBS, PRTH
COMMON /INPUT0/ GRDFLO, MINERD, PRTOBS(MAXOBS), PRTH(MAXTH)
COMMON /INPUT1/ ISEED, IMBKD, IOBS, ISPVAR, ITH, LHSVBP, NOBS,
1      NPF, NTH, NSPC, NREG, NBP, NPP
COMMON /INPUT2/ SMT, VBT, TOTACT, ACTI, ACTS, TSMAX, TSLIM,
1      TEND, TENDBH, STPRST, DD1, DD2, DDTIME, PPP(3),
2      DM1, DM2, DMTIME, TOL, RTOL, RPTOL, BUFFRC,
3      GRAV, PI, ECULEB, ECASTI, PCULEB, PCASTI,
4      DIAMNA, DIAMXA, DIAMNB, DIAMXB, DMODA, DMODB,
5      PRMNA, PRMNA, PRMNB, PRMNB, PMODA, PMODB,
6      BRNDEN, BRNVIS
COMMON /BLOW1/ NTBC, NTBLE0, NTBUE0,
1      NTBSE11, NTBDE11, NTBSE21, NTBDE21,
2      NTBSE12(MAXTIM), NTBDE12(MAXTIM),
3      NTBSE22(MAXTIM), NTBDE22(MAXTIM)
COMMON /BLOW2/ TBC(MAXTIM), CBE0(MAXTIM),
1      CBE1(MAXTIM), CBE2(MAXTIM),
2      TBLE0(MAXTIM), TBUE0(MAXTIM),

```

```

3          RBLE0(MAXTIM), RBUE0(MAXTIM),
4          TBSE1(MAXTIM,MAXTIM), RBSE1(MAXTIM,MAXTIM),
5          TBDE1(MAXTIM,MAXTIM), RBDE1(MAXTIM,MAXTIM),
6          TBSE2(MAXTIM,MAXTIM), RBSE2(MAXTIM,MAXTIM),
7          TBDE2(MAXTIM,MAXTIM), RBDE2(MAXTIM,MAXTIM)
CHARACTER LABSET(MAXREC,NUSED,NTWO)*48
CHARACTER LNOUSE(NOTUSE)*38, LINE3(NUSED)*30
CHARACTER SLABEL(MAXREC,NUSED,NTWO)*55
CHARACTER BLABEL(MAXREC,NUSED,NTWO)*55
COMMON /LABEL1/ BLABEL, LABSET, LINE3, LNOUSE
COMMON /LABEL2/ SLABEL
C
C
C*****READ FLAGS ON BLOWOUT RELEASES TITLE RECORD
      READ(2,911,ERR=9200,END=9300) IOBST, IFLG, LABSET(IOBS,3,1)
911  FORMAT(2I10,A48)
C      WRITE(*,*) IOBST,IFLG,IOBS
C*****VALIDATE OBSERVATION INDEX
      IF (IOBST .NE. IOBS) THEN
C*****INVALID OBSERVATION INDEX VALUE
          WRITE(11,*) '>>>>INVALID OBSERVATION INDEX VALUE FOR ',
1          'BLOWOUT RELEASE TABLES'
          WRITE(6,*) '>>>>ERROR(Q) ENCOUNTERED, EXECUTION TERMINATED'
          STOP
          ENDIF
C*****CHECK FLAG FOR READING RELEASE TABLES
      IF (IFLG .EQ. 0) RETURN
C*****LABEL BLOWOUT HEADER RECORD FOR CONCENTRATIONS
      READ(2,912,ERR=9200,END=9300) LABSET(IOBS,3,2)
912  FORMAT(A48)
C*****READ CONCENTRATION VALUES FOR BLOWOUT RELEASES
      READ(2,*,ERR=9200,END=9300) NTBC, (TBC(IT),IT=1,NTBC),
1          (CBE0(IT),IT=1,NTBC),
2          (CBE1(IT),IT=1,NTBC),
3          (CBE2(IT),IT=1,NTBC)
C*****LABEL BLOWOUT HEADER RECORD FOR UNDISTURBED CONDITIONS (LOWER PANELS)
      READ(2,913,ERR=9200,END=9300) BLABEL(IOBS,1,1)
913  FORMAT(A55)
C*****READ BLOWOUT RELEASES FOR UNDISTURBED CONDITIONS (LOWER PANELS)
      READ(2,*,ERR=9200,END=9300) NTBLE0, (TBLE0(IT),IT=1,NTBLE0),
1          (RBLE0(IT),IT=1,NTBLE0)
C*****LABEL BLOWOUT HEADER RECORD FOR UNDISTURBED CONDITIONS (UPPER PANELS)

```

```

      READ(2,913,ERR=9200,END=9300) BLABEL(IOBS,1,2)
C*****READ BLOWOUT RELEASES FOR UNDISTURBED CONDITIONS (UPPER PANELS)
      READ(2,*,ERR=9200,END=9300) NTBUE0, (TBUE0(IT),IT=1,NTBUE0),
1          (RBUE0(IT),IT=1,NTBUE0)
C*****LABEL BLOWOUT HEADER RECORD FOR E1 INTRUSIONS (SAME PANEL)
      READ(2,913,ERR=9200,END=9300) BLABEL(IOBS,2,1)
C*****READ BLOWOUT RELEASES FOR E1 INTRUSIONS (SAME PANEL)
      READ(2,*,ERR=9200,END=9300) NTBSE11, (NTBSE12(IT1),
1          (TBSE1(IT2,IT1),IT2=1,NTBSE12(IT1))),
2          (RBSE1(IT2,IT1),IT2=1,NTBSE12(IT1)), IT1=1,NTBSE11)
C*****LABEL BLOWOUT HEADER RECORD FOR E1 INTRUSIONS (DIFFERENT PANEL)
      READ(2,913,ERR=9200,END=9300) BLABEL(IOBS,2,2)
C*****READ BLOWOUT RELEASES FOR E1 INTRUSIONS (DIFFERENT PANEL)
      READ(2,*,ERR=9200,END=9300) NTBDE11, (NTBDE12(IT1),
1          (TBDE1(IT2,IT1),IT2=1,NTBDE12(IT1))),
2          (RBDE1(IT2,IT1),IT2=1,NTBDE12(IT1)), IT1=1,NTBDE11)
C*****LABEL BLOWOUT HEADER RECORD FOR E2 INTRUSIONS (SAME PANEL)
      READ(2,913,ERR=9200,END=9300) BLABEL(IOBS,3,1)
C*****READ BLOWOUT RELEASES FOR E2 INTRUSIONS (SAME PANEL)
      READ(2,*,ERR=9200,END=9300) NTBSE21, (NTBSE22(IT1),
1          (TBSE2(IT2,IT1),IT2=1,NTBSE22(IT1))),
2          (RBSE2(IT2,IT1),IT2=1,NTBSE22(IT1)), IT1=1,NTBSE21)
C*****LABEL BLOWOUT HEADER RECORD FOR E2 INTRUSIONS (DIFFERENT PANEL)
      READ(2,913,ERR=9200,END=9300) BLABEL(IOBS,3,2)
C*****READ BLOWOUT RELEASES FOR E2 INTRUSIONS (DIFFERENT PANEL)
      READ(2,*,ERR=9200,END=9300) NTBDE21, (NTBDE22(IT1),
1          (TBDE2(IT2,IT1),IT2=1,NTBDE22(IT1))),
2          (RBDE2(IT2,IT1),IT2=1,NTBDE22(IT1)), IT1=1,NTBDE21)
C*****VALIDATE TIME RANGE FOR BLOWOUT RELEASES
      IF ((TBC(1) .GT. ACTI) .OR.
1      (TBLE0(1) .GT. ACTI) .OR. (TBUE0(1) .GT. ACTI) .OR.
2      (TBSE1(1,1) .GT. ACTI) .OR. (TBDE1(1,1) .GT. ACTI) .OR.
3      (TBSE2(1,1) .GT. ACTI) .OR. (TBDE2(1,1) .GT. ACTI)) THEN
      WRITE(11,*) '>>>>BLOWOUT RELEASE TABLE DOES NOT SPAN ',
1          'POTENTIAL INTRUSION TIMES'
      WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
      WRITE(6,*) '>>>>ERROR(R) ENCOUNTERED, EXECUTION TERMINATED'
      STOP
      ENDIF
C*****DETERMINE MAXIMUM COUNTER FOR BLOWOUT RELEASE TABLES
      NTBMAX=MAX (NTBC, NTBLE0, NTBUE0, NTBSE11, NTBDE11, NTBSE21,
1          NTBDE21)

```

```

C*****VALIDATE TIME RANGE FOR BLOWOUT RELEASES
      IF ((TBC(NTBC) .LT. TEND) .OR. (TBLE0(NTBLE0) .LT. TEND) .OR.
1      (TBUE0(NTBUE0) .LT. TEND)) THEN
      WRITE(11,*) '>>>>BLOWOUT RELEASE TABLE DOES NOT SPAN ',
1      'POTENTIAL INTRUSION TIMES'
      WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
      WRITE(6,*) '>>>>ERROR(S) ENCOUNTERED, EXECUTION TERMINATED'
      STOP
      ENDIF
      DO 2100 IT1=1,NTBSE11
      NTBMAX=MAX (NTBMAX, NTBSE12(IT1))
C*****VALIDATE TIME RANGE FOR BLOWOUT RELEASES
      IF (TBSE1(NTBSE12(IT1),IT1) .LT. TEND) THEN
      WRITE(11,*) '>>>>BLOWOUT RELEASE TABLE DOES NOT SPAN ',
1      'POTENTIAL INTRUSION TIMES'
      WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
      WRITE(6,*) '>>>>ERROR(T) ENCOUNTERED, EXECUTION TERMINATED'
      STOP
      ENDIF
2100 CONTINUE
      DO 2150 IT1=1,NTBDE11
      NTBMAX=MAX (NTBMAX, NTBDE12(IT1))
C*****VALIDATE TIME RANGE FOR BLOWOUT RELEASES
      IF (TBDE1(NTBDE12(IT1),IT1) .LT. TEND) THEN
      WRITE(11,*) '>>>>BLOWOUT RELEASE TABLE DOES NOT SPAN ',
1      'POTENTIAL INTRUSION TIMES'
      WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
      WRITE(6,*) '>>>>ERROR(U) ENCOUNTERED, EXECUTION TERMINATED'
      STOP
      ENDIF
2150 CONTINUE
      DO 2200 IT1=1,NTBSE21
      NTBMAX=MAX (NTBMAX, NTBSE22(IT1))
C*****VALIDATE TIME RANGE FOR BLOWOUT RELEASES
      IF (TBSE2(NTBSE22(IT1),IT1) .LT. TEND) THEN
      WRITE(11,*) '>>>>BLOWOUT RELEASE TABLE DOES NOT SPAN ',
1      'POTENTIAL INTRUSION TIMES'
      WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
      WRITE(6,*) '>>>>ERROR(V) ENCOUNTERED, EXECUTION TERMINATED'
      STOP
      ENDIF
2200 CONTINUE

```

```

DO 2250 IT1=1,NTBDE21
  NTBMAX=MAX (NTBMAX, NTBDE22(IT1))
C*****VALIDATE TIME RANGE FOR BLOWOUT RELEASES
  IF (TBDE2(NTBDE22(IT1),IT1) .LT. TEND) THEN
    WRITE(11,*) '>>>>BLOWOUT RELEASE TABLE DOES NOT SPAN ',
1      'POTENTIAL INTRUSION TIMES'
    WRITE(11,*) '>>>>(', ACTI, ' TO ', TEND, ' YR)'
    WRITE(6,*) '>>>>ERROR(W) ENCOUNTERED, EXECUTION TERMINATED'
    STOP
  ENDIF
2250 CONTINUE
C*****VALIDATE MAXIMUM COUNTER FOR BLOWOUT RELEASE TABLES
  IF (NTBMAX .GT. MAXTIM) THEN
    WRITE(11,*) '>>>>INCREASE VALUE OF PARAMETER MAXTIM TO AT ',
1      'LEAST ', NTBMAX
    WRITE(6,*) '>>>>ERROR(X) ENCOUNTERED, EXECUTION TERMINATED'
    STOP
  ENDIF
C*****VALIDATE 1ST INTRUSION TIMES (INCREASING ORDER), UNDISTURBED CONDITIONS
DO 2300 IT=2,NTBLE0
  IF (TBLE0(IT) .LE. TBLE0(IT-1)) THEN
    WRITE(11,*) '>>>>BLOWOUT RELEASE TIMES FOR UNDISTURBED ',
1      'CONDITIONS NOT IN INCREASING ORDER'
    WRITE(6,*) '>>>>ERROR(Y) ENCOUNTERED, EXECUTION TERMINATED'
    STOP
  ENDIF
2300 CONTINUE
DO 2350 IT=2,NTBUE0
  IF (TBUE0(IT) .LE. TBUE0(IT-1)) THEN
    WRITE(11,*) '>>>>BLOWOUT RELEASE TIMES FOR UNDISTURBED ',
1      'CONDITIONS NOT IN INCREASING ORDER'
    WRITE(6,*) '>>>>ERROR(Z) ENCOUNTERED, EXECUTION TERMINATED'
    STOP
  ENDIF
2350 CONTINUE
C*****VALIDATE 1ST INTRUSION TIMES (INCREASING ORDER), E1 INTRUSIONS
DO 2400 IT1=2,NTBSE11
  IF (TBSE1(1,IT1) .LE. TBSE1(1,IT1-1)) THEN
    WRITE(11,*) '>>>>BLOWOUT RELEASE TIMES FOR E1 INTRUSIONS ',
1      'NOT IN INCREASING ORDER'
    WRITE(6,*) '>>>>ERROR(a) ENCOUNTERED, EXECUTION TERMINATED'
    STOP

```

```

        ENDIF
2400 CONTINUE
        DO 2450 IT1=2,NTBDE11
            IF (TBDE1(1,IT1) .LE. TBDE1(1,IT1-1)) THEN
                WRITE(11,*) '>>>>BLOWOUT RELEASE TIMES FOR E1 INTRUSIONS ',
1                'NOT IN INCREASING ORDER'
                WRITE(6,*) '>>>>ERROR(b) ENCOUNTERED, EXECUTION TERMINATED'
                STOP
            ENDIF
2450 CONTINUE
C*****VALIDATE 2ND INTRUSION TIMES (INCREASING ORDER), E1 INTRUSIONS
        DO 2600 IT1=1,NTBSE11
            DO 2500 IT2=2,NTBSE12(IT1)
                IF (TBSE1(IT2,IT1) .LE. TBSE1(IT2-1,IT1)) THEN
                    WRITE(11,*) '>>>>BLOWOUT RELEASE TIMES FOR E1 ',
1                    'INTRUSIONS NOT IN INCREASING ORDER'
                    WRITE(6,*) '>>>>ERROR(d) ENCOUNTERED, EXECUTION ',
1                    'TERMINATED'
                    STOP
                ENDIF
2500 CONTINUE 2600 CONTINUE
            DO 2650 IT1=1,NTBDE11
                DO 2550 IT2=2,NTBDE12(IT1)
                    IF (TBDE1(IT2,IT1) .LE. TBDE1(IT2-1,IT1)) THEN
                        WRITE(11,*) '>>>>BLOWOUT RELEASE TIMES FOR E1 ',
1                        'INTRUSIONS NOT IN INCREASING ORDER'
                        WRITE(6,*) '>>>>ERROR(e) ENCOUNTERED, EXECUTION ',
1                        'TERMINATED'
                        STOP
                    ENDIF
2550 CONTINUE
2650 CONTINUE
C*****VALIDATE 1ST INTRUSION TIMES (INCREASING ORDER), E2 INTRUSIONS
        DO 2700 IT1=2,NTBSE21
            IF (TBSE2(1,IT1) .LE. TBSE2(1,IT1-1)) THEN
                WRITE(11,*) '>>>>BLOWOUT RELEASE TIMES FOR E2 ',
1                'INTRUSIONS NOT IN INCREASING ORDER'
                WRITE(6,*) '>>>>ERROR(f) ENCOUNTERED, EXECUTION TERMINATED'
                STOP
            ENDIF
2700 CONTINUE
        DO 2750 IT1=2,NTBDE21

```

```

        IF (TBDE2(1,IT1) .LE. TBDE2(1,IT1-1)) THEN
            WRITE(11,*) '>>>>BLOWOUT RELEASE TIMES FOR E2 INTRUSIONS ',
1            'NOT IN INCREASING ORDER'
            WRITE(6,*) '>>>>ERROR(g) ENCOUNTERED, EXECUTION TERMINATED'
            STOP
        ENDIF
2750 CONTINUE
C*****VALIDATE 2ND INTRUSION TIMES (INCREASING ORDER), E2 INTRUSIONS
        DO 2900 IT1=1,NTBSE21
            DO 2800 IT2=2,NTBSE22(IT1)
                IF (TBSE2(IT2,IT1) .LE. TBSE2(IT2-1,IT1)) THEN
                    WRITE(11,*) '>>>>BLOWOUT RELEASE TIMES FOR E2 ',
1                    'INTRUSIONS NOT IN INCREASING ORDER'
                    WRITE(6,*) '>>>>ERROR(h) ENCOUNTERED, EXECUTION ',
1                    'TERMINATED'
                    STOP
                ENDIF
2800 CONTINUE
2900 CONTINUE
        DO 2950 IT1=1,NTBDE21
            DO 2850 IT2=2,NTBDE22(IT1)
                IF (TBDE2(IT2,IT1) .LE. TBDE2(IT2-1,IT1)) THEN
                    WRITE(11,*) '>>>>BLOWOUT RELEASE TIMES FOR E2 ',
1                    'INTRUSIONS NOT IN INCREASING ORDER'
                    WRITE(6,*) '>>>>ERROR(i) ENCOUNTERED, EXECUTION ',
1                    'TERMINATED'
                    STOP
                ENDIF
2850 CONTINUE
2950 CONTINUE
        RETURN
C*****I/O ERROR READING BLOWOUT RELEASE TABLES
9200 CONTINUE
        WRITE(11,*) '>>>>I/O ERROR READING BLOWOUT RELEASE TABLES'
        WRITE(6,*) '>>>>ERROR(j) ENCOUNTERED, EXECUTION TERMINATED'
        STOP
C*****PREMATURE EOF ENCOUNTERED READING BLOWOUT RELEASE TABLES
9300 CONTINUE
        WRITE(11,*) '>>>>PREMATURE EOF ENCOUNTERED READING ',
1        'BLOWOUT RELEASE TABLES'
        WRITE(6,*) '>>>>ERROR(k) ENCOUNTERED, EXECUTION TERMINATED'
        STOP

```

```

      END
C
C.....^.....
      SUBROUTINE READR
C*****READ RELEASE TABLES FOR CURRENT OBSERVATION
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      PARAMETER (MXY=20, MAXREC=100, MAXBH=100, MAXRES=50, MAXBIN=161,
1          MAXSPC=10, MAXSC=30, MAXOBS=100, MAXTH=10000,
2          MAXTIM=20, MAXBP=5, MAXACT=1000, MAXTC=200,
3          MAXVAR=100, MAXREG=5, NEQM=MXY*MXY, IBWM=3*MXY+1,
4          NUSED=3, NOTUSE=5, NTWO=2)
      CHARACTER LABSET(MAXREC,NUSED,NTWO)*48
      CHARACTER LNOUSE(NOTUSE)*38, LINE3(NUSED)*30
      CHARACTER SLABEL(MAXREC,NUSED,NTWO)*55
      CHARACTER BLABEL(MAXREC,NUSED,NTWO)*55
      COMMON /LABEL1/ BLABEL, LABSET, LINE3, LNOUSE
      COMMON /LABEL2/ SLABEL
C
C
C*****READ CUTTINGS RELEASE TABLES
      CALL RDCUT C*****READ SPALLINGS RELEASE TABLES
      CALL RDSPL
C*****READ BLOWOUT RELEASE TABLES
      CALL RDBLW
C*****READ MARKER BED RELEASE TABLES
C      CALL RDMB
      READ(2,900) LNOUSE(1)
      900 FORMAT(20X,A38)
C*****READ DEWEY LAKES RELEASE TABLES
C      CALL RDDDL
      READ(2,900) LNOUSE(2)
C*****READ SURFACE RELEASE TABLES
C      CALL RDSURF
      READ(2,900) LNOUSE(3)
C*****READ FLOW TO CULEBRA RELEASE TABLES
C      CALL RDCULT
      READ(2,900) LNOUSE(4)
C*****READ CULEBRA TRANSPORT RELEASE TABLES
C      CALL RDCULF
      READ(2,900) LNOUSE(5)
      RETURN
      END

```

C

C.....^.....

SUBROUTINE DOUBLE

C*****PRINT DOUBLED RELEASE TABLES

IMPLICIT DOUBLE PRECISION (A-H, O-Z)

INTEGER INDIC(3)

PARAMETER (MXY=20, MAXREC=100, MAXBH=100, MAXRES=50, MAXBIN=161,

1 MAXSPC=10, MAXSC=30, MAXOBS=100, MAXTH=10000,

2 MAXTIM=20, MAXBP=5, MAXACT=1000, MAXTC=200,

3 MAXVAR=100, MAXREG=5, NEQM=MXY*MXY, IBWM=3*MXY+1,

4 NUSED=3, NOTUSE=5, NTWO=2)

LOGICAL GRDFLO, MINERD, PRTOBS, PRTH

COMMON /INPUT0/ GRDFLO, MINERD, PRTOBS(MAXOBS), PRTH(MAXTH)

COMMON /INPUT1/ ISEED, IMBKCD, IOBS, ISPVAR, ITH, LHSVBP, NOBS,

1 NPF, NTH, NSPC, NREG, NBP, NPP

COMMON /INPUT2/ SMT, VBT, TOTACT, ACTI, ACTS, TSMAX, TSLIM,

1 TEND, TENDBH, STPRST, DD1, DD2, DDTIME, PPP(3),

2 DM1, DM2, DMTIME, TOL, RTOL, RPTOL, BUFFRC,

3 GRAV, PI, ECULEB, ECASTI, PCULEB, PCASTI,

4 DIAMNA, DIAMXA, DIAMNB, DIAMXB, DMODA, DMODB,

5 PRMMNA, PRMMXA, PRMMNB, PRMMXB, PMODA, PMODB,

6 BRNDEN, BRNVIS

COMMON /BLOW1/ NTBC, NTBLE0, NTBUE0,

1 NTBSE11, NTBDE11, NTBSE21, NTBDE21,

2 NTBSE12(MAXTIM), NTBDE12(MAXTIM),

3 NTBSE22(MAXTIM), NTBDE22(MAXTIM)

COMMON /BLOW2/ TBC(MAXTIM), CBE0(MAXTIM),

1 CBE1(MAXTIM), CBE2(MAXTIM),

2 TBLE0(MAXTIM), TBUE0(MAXTIM),

3 RBLE0(MAXTIM), RBUE0(MAXTIM),

4 TBSE1(MAXTIM,MAXTIM), RBSE1(MAXTIM,MAXTIM),

5 TBDE1(MAXTIM,MAXTIM), RBDE1(MAXTIM,MAXTIM),

6 TBSE2(MAXTIM,MAXTIM), RBSE2(MAXTIM,MAXTIM),

7 TBDE2(MAXTIM,MAXTIM), RBDE2(MAXTIM,MAXTIM)

COMMON /SPAL1/ NTSC, NTSLE0, NTSUE0,

1 NTSSE11, NTSDE11, NTSSE21, NTSDE21,

1 NTSSE12(MAXTIM), NTSDE12(MAXTIM),

2 NTSSE22(MAXTIM), NTSDE22(MAXTIM)

COMMON /SPAL2/ TSC(MAXTIM), CSA(MAXTIM),

1 TSLE0(MAXTIM), TSUE0(MAXTIM),

2 RSLE0(MAXTIM), RSUE0(MAXTIM),

3 TSSE1(MAXTIM,MAXTIM), RSSE1(MAXTIM,MAXTIM),

```

4          TSDE1(MAXTIM,MAXTIM), RSDE1(MAXTIM,MAXTIM),
5          TSSE2(MAXTIM,MAXTIM), RSSE2(MAXTIM,MAXTIM),
6          TSDE2(MAXTIM,MAXTIM), RSDE2(MAXTIM,MAXTIM)
COMMON /CUT1/ NTCH, NTRH, NCH, NRH, NACH, NARH
COMMON /CUT2/ DBDIAM, ACH, ARH, FVCH, FVRH, HCH, HRH,
1          PCUT(MAXACT), TCH(MAXTIM), TRH(MAXTIM),
2          RCUT(MAXTIM,MAXACT), PWT(3,MAXREG)
CHARACTER LABSET(MAXREC,NUSED,NTWO)*48
CHARACTER LNOUSE(NOTUSE)*38, LINE3(NUSED)*30
CHARACTER SLABEL(MAXREC,NUSED,NTWO)*55
CHARACTER BLABEL(MAXREC,NUSED,NTWO)*55
COMMON /LABEL1/ BLABEL, LABSET, LINE3, LNOUSE
COMMON /LABEL2/ SLABEL
C
C
IFLG=1
IONE=1
INDIC(1)=1
INDIC(2)=1      INDIC(3)=1
IF(IOBS.GT.1) IFLG=0
IF(IFLG.EQ.1) THEN
  FACTOR=-1.0
  WRITE(*,*) 'ENTER SCALING FACTOR (>0)'
  READ(*,*) FACTOR
  IF(FACTOR.LE.0.) STOP 'STOP: REQUIRE POSITIVE FACTOR'
  FACTCU=FACTOR*INDIC(1)
  FACTSP=FACTOR*INDIC(2)
  FACTBL=FACTOR*INDIC(3)
  LEND=LABEND(LINE3(1),30)
  WRITE(12,900) (LINE3(1)(L:L),L=1,LEND)
  LEND=LABEND(LINE3(2),30)
  WRITE(12,900) (LINE3(2)(L:L),L=1,LEND)
900  FORMAT(55A1)
  LEND=LABEND(LINE3(3),30)
  WRITE(12,921) NOBS,(LINE3(3)(L:L),L=1,LEND)
921  FORMAT(I10,55A1)
ENDIF
LEND=LABEND(LABSET(IOBS,1,1),48)
C*****WRITE FLAGS ON CUTTINGS RELEASES TITLE RECORD
  WRITE(12,901) IOBS, IFLG, (LABSET(IOBS,1,1)(L:L),L=1,LEND)
901  FORMAT(2I10,55A1)
C*****WRITE NUMBER OF TIMES, NUMBER OF WASTE TYPES, WASTE AREA,

```

```

C*****WASTE HEIGHT, VOLUME FRACTION, AND DRILL BIT DIAMETER FOR CH WASTE
      WRITE(12,922) NTCH, NCH, ACH, HCH, FVCH, DBDIAM
922  FORMAT(2I10,1P,14E10.3)
C*****WRITE NUMBER OF TIMES, NUMBER OF WASTE TYPES, WASTE AREA,
C*****WASTE HEIGHT, AND VOLUME FRACTION FOR RH WASTE
      WRITE(12,922) NTRH, NRH, ARH, HRH, FVRH
C*****WRITE PROBABILITIES ASSOCIATED WITH EACH ACTIVITY LEVEL FOR
C*****CH AND RH WASTES
      IF(IFLG.LT.1) GOTO 199
      WRITE(12,903) PCUT(1), (PCUT(ICH)-PCUT(ICH-1), ICH=2, NCH),
1          (PCUT(NCH+IRH), IRH=1, NRH)
903  FORMAT(1P,8E10.3)
C*****WRITE TIMES FOR ACTIVITY LEVELS FOR CH WASTE
      WRITE(12,903) (TCH(IT), IT=1, NTCH)
C*****WRITE TIMES FOR ACTIVITY LEVELS FOR RH WASTE
      WRITE(12,903) (TRH(IT), IT=1, NTRH)
C*****WRITE RELEASES FOR ALL TIMES FOR CH AND RH WASTE
      WRITE(12,903) ((FACTCU*RCUT(IT, ICH), IT=1, NTCH), ICH=1, NCH),
1          ((FACTCU*RCUT(IT, NCH+IRH), IT=1, NTRH), IRH=1, NRH)
C
C
199  LEND=LABEND(LABSET(IOBS, 2, 1), 48)
      WRITE(12,901) IOBS, IONE, (LABSET(IOBS, 2, 1)(L:L), L=1, LEND)
C*****LABEL SPALLINGS HEADER RECORD FOR CONCENTRATIONS
      LEND=LABEND(LABSET(IOBS, 2, 2), 48)
      WRITE(12,948) (LABSET(IOBS, 2, 2)(L:L), L=1, LEND)
948  FORMAT(55A1)
C*****WRITE CONCENTRATION VALUES FOR SPALLINGS RELEASES
      WRITE(12,904) NTSC, (TSC(IT), IT=1, NTSC),
1          (CSA(IT), IT=1, NTSC)
904  FORMAT(I10,1P,2(/8E10.3/E10.3))
C*****LABEL SPALLINGS HEADER RECORD FOR UNDISTURBED CONDITIONS (LOWER PANELS)
      LEND=LABEND(SLABEL(IOBS, 1, 1), 55)
      WRITE(12,902) (SLABEL(IOBS, 1, 1)(L:L), L=1, LEND)
902  FORMAT(55A1)
C*****WRITE SPALLINGS RELEASES FOR UNDISTURBED CONDITIONS (LOWER PANELS)
      WRITE(12,905) NTSLE0, (TSLE0(IT), IT=1, NTSLE0),
1          (FACTSP*RSLE0(IT), IT=1, NTSLE0)
905  FORMAT(I10/1P,6E10.3/6E10.3)
C*****LABEL SPALLINGS HEADER RECORD FOR UNDISTURBED CONDITIONS (UPPER PANELS)
      LEND=LABEND(SLABEL(IOBS, 1, 2), 55)
      WRITE(12,902) (SLABEL(IOBS, 1, 2)(L:L), L=1, LEND)

```

```

C*****WRITE SPALLINGS RELEASES FOR UNDISTURBED CONDITIONS (UPPER PANELS)
      WRITE(12,905) NTSUE0, (TSUE0(IT),IT=1,NTSUE0),
1          (FACTSP*RSUE0(IT),IT=1,NTSUE0)
C*****LABEL SPALLINGS HEADER RECORD FOR E1 INTRUSIONS (SAME PANEL)
      LEND=LABEND(SLABEL(IOBS,2,1),55)
      WRITE(12,902) (SLABEL(IOBS,2,1)(L:L),L=1,LEND)
C*****WRITE SPALLINGS RELEASES FOR E1 INTRUSIONS (SAME PANEL)
      WRITE(12,906) NTSSE11, (NTSSE12(IT1),
1          (TSSE1(IT2,IT1),IT2=1,NTSSE12(IT1))),
2  (FACTSP*RSSE1(IT2,IT1),IT2=1,NTSSE12(IT1)), IT1=1,NTSSE11)
906  FORMAT(I10/,I10/,1P,2(8E10.3/),
1      I10/,2(6E10.3/),I10/,2(6E10.3/),I10/,2(6E10.3/),
2      I10/,2(6E10.3/),I10/,2(5E10.3/),I10/,E10.3/E10.3)
C*****LABEL SPALLINGS HEADER RECORD FOR E1 INTRUSIONS (DIFFERENT PANEL)
      LEND=LABEND(SLABEL(IOBS,2,2),55)
      WRITE(12,902) (SLABEL(IOBS,2,2)(L:L),L=1,LEND)
C*****WRITE SPALLINGS RELEASES FOR E1 INTRUSIONS (DIFFERENT PANEL)
      WRITE(12,906) NTSDE11, (NTSDE12(IT1),
1          (TSDE1(IT2,IT1),IT2=1,NTSDE12(IT1))),
2  (FACTSP*RSDE1(IT2,IT1),IT2=1,NTSDE12(IT1)), IT1=1,NTSDE11)
C*****LABEL SPALLINGS HEADER RECORD FOR E2 INTRUSIONS (SAME PANEL)
      LEND=LABEND(SLABEL(IOBS,3,1),55)
      WRITE(12,902) (SLABEL(IOBS,3,1)(L:L),L=1,LEND)
C*****WRITE SPALLINGS RELEASES FOR E2 INTRUSIONS (SAME PANEL)
      WRITE(12,906) NTSSE21, (NTSSE22(IT1),
1          (TSSE2(IT2,IT1),IT2=1,NTSSE22(IT1))),
2  (FACTSP*RSSE2(IT2,IT1),IT2=1,NTSSE22(IT1)), IT1=1,NTSSE21)
C*****LABEL SPALLINGS HEADER RECORD FOR E2 INTRUSIONS (DIFFERENT PANEL)
      LEND=LABEND(SLABEL(IOBS,3,2),55)
      WRITE(12,902) (SLABEL(IOBS,3,2)(L:L),L=1,LEND)
C*****WRITE SPALLINGS RELEASES FOR E2 INTRUSIONS (DIFFERENT PANEL)
      WRITE(12,906) NTSDE21, (NTSDE22(IT1),
1          (TSDE2(IT2,IT1),IT2=1,NTSDE22(IT1))),
2  (FACTSP*RSDE2(IT2,IT1),IT2=1,NTSDE22(IT1)), IT1=1,NTSDE21)
C
C
C*****WRITE FLAGS ON BLOWOUT RELEASES TITLE RECORD
      LEND=LABEND(LABSET(IOBS,3,1),48)
      WRITE(12,901) IOBS, IONE, (LABSET(IOBS,3,1)(L:L),L=1,LEND)
C*****LABEL BLOWOUT HEADER RECORD FOR CONCENTRATIONS
      LEND=LABEND(LABSET(IOBS,3,2),48)
      WRITE(12,948) (LABSET(IOBS,3,2)(L:L),L=1,LEND)

```

```

C*****WRITE CONCENTRATION VALUES FOR BLOWOUT RELEASES
      WRITE(12,907) NTBC, (TBC(IT),IT=1,NTBC),
1          (CBE0(IT),IT=1,NTBC),
2          (CBE1(IT),IT=1,NTBC),
3          (CBE2(IT),IT=1,NTBC)
907  FORMAT(I10,1P,4(/8E10.3/E10.3))
C*****LABEL BLOWOUT HEADER RECORD FOR UNDISTURBED CONDITIONS (LOWER PANELS)
      LEND=LABEND(BLABEL(IOBS,1,1),55)
      WRITE(12,902) (BLABEL(IOBS,1,1)(L:L),L=1,LEND)
C*****WRITE BLOWOUT RELEASES FOR UNDISTURBED CONDITIONS (LOWER PANELS)
      WRITE(12,905) NTBLE0, (TBLE0(IT),IT=1,NTBLE0),
1          (FACTBL*RBLE0(IT),IT=1,NTBLE0)
C*****LABEL BLOWOUT HEADER RECORD FOR UNDISTURBED CONDITIONS (UPPER PANELS)
      LEND=LABEND(BLABEL(IOBS,1,2),55)
      WRITE(12,902) (BLABEL(IOBS,1,2)(L:L),L=1,LEND)
C*****WRITE BLOWOUT RELEASES FOR UNDISTURBED CONDITIONS (UPPER PANELS)
      WRITE(12,905) NTBUE0, (TBUE0(IT),IT=1,NTBUE0),
1          (FACTBL*RBUE0(IT),IT=1,NTBUE0)
C*****LABEL BLOWOUT HEADER RECORD FOR E1 INTRUSIONS (SAME PANEL)
      LEND=LABEND(BLABEL(IOBS,2,1),55)
      WRITE(12,902) (BLABEL(IOBS,2,1)(L:L),L=1,LEND)
C*****WRITE BLOWOUT RELEASES FOR E1 INTRUSIONS (SAME PANEL)
      WRITE(12,906) NTBSE11, (NTBSE12(IT1),
1          (TBSE1(IT2,IT1),IT2=1,NTBSE12(IT1))),
2  (FACTBL*RBSE1(IT2,IT1),IT2=1,NTBSE12(IT1)), IT1=1,NTBSE11)
C*****LABEL BLOWOUT HEADER RECORD FOR E1 INTRUSIONS (DIFFERENT PANEL)
      LEND=LABEND(BLABEL(IOBS,2,2),55)
      WRITE(12,902) (BLABEL(IOBS,2,2)(L:L),L=1,LEND)
C*****WRITE BLOWOUT RELEASES FOR E1 INTRUSIONS (DIFFERENT PANEL)
      WRITE(12,906) NTBDE11, (NTBDE12(IT1),
1          (TBDE1(IT2,IT1),IT2=1,NTBDE12(IT1))),
2  (FACTBL*RBDE1(IT2,IT1),IT2=1,NTBDE12(IT1)), IT1=1,NTBDE11)
C*****LABEL BLOWOUT HEADER RECORD FOR E2 INTRUSIONS (SAME PANEL)
      LEND=LABEND(BLABEL(IOBS,3,1),55)
      WRITE(12,902) (BLABEL(IOBS,3,1)(L:L),L=1,LEND)
C*****WRITE BLOWOUT RELEASES FOR E2 INTRUSIONS (SAME PANEL)
      WRITE(12,906) NTBSE21, (NTBSE22(IT1),
1          (TBSE2(IT2,IT1),IT2=1,NTBSE22(IT1))),
2  (FACTBL*RBSE2(IT2,IT1),IT2=1,NTBSE22(IT1)), IT1=1,NTBSE21)
C*****LABEL BLOWOUT HEADER RECORD FOR E2 INTRUSIONS (DIFFERENT PANEL)
      LEND=LABEND(BLABEL(IOBS,3,2),55)
      WRITE(12,902) (BLABEL(IOBS,3,2)(L:L),L=1,LEND)

```

```

C*****WRITE BLOWOUT RELEASES FOR E2 INTRUSIONS (DIFFERENT PANEL)
      WRITE(12,906) NTBDE21, (NTBDE22(IT1),
1         (TBDE2(IT2,IT1),IT2=1,NTBDE22(IT1)),
2  (FACTBL*RBDE2(IT2,IT1),IT2=1,NTBDE22(IT1)), IT1=1,NTBDE21)
      DO 100 KK=1,5
          LEND=LABEND(LNOUSE(KK),38)
100     WRITE(12,908) IOBS, 0, (LNOUSE(KK)(L:L),L=1,LEND)
908     FORMAT(2I10,55A1)
      RETURN
      END

C
C.....^.....
      INTEGER FUNCTION LABEND(STR,JEND)
      CHARACTER STR*(*)
      LABEND=0
C     WRITE(*,*) JEND
      DO 1000 J=1,JEND
          JB=JEND+1-J
          IF(STR(JB:JB).NE.' ') THEN
              LABEND=JB
              RETURN
          ENDIF
1000    CONTINUE
      RETURN
      END

```

FORTRAN PROGRAMS USED FOR BILINEARITY TEST

CCG.FOR

```

C*****READ CCDF.OUT FILE AND DIVIDE RELEASES BY INPUT FACTOR (.NEW)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      PARAMETER (MAXBIN=161,MAXRES=50)
      CHARACTER RLAB(0:MAXRES)*30, TITLEP*130
      DIMENSION CUMPRB(MAXBIN), VAL(MAXBIN), RMEAN(0:MAXRES),
1  PNZERO(0:MAXRES),PEAK(0:MAXRES),PPEAK(0:MAXRES),RSCMIN(0:MAXRES)
C
      OPEN(14,FILE='CCGF_T2_PA96.OUT',STATUS='UNKNOWN')
      OPEN(20,FILE='CCGF_T2_PA96.NEW',STATUS='UNKNOWN',RECL=1000)
C     OPEN(14,FILE='CCGF_T2.OUT')
C     OPEN(20,FILE='CCGF_T2.NEW')
C
C*****SET RESULT LABELS, WILL BE REPLACED ON READ
      RLAB(0)='Buffer'

```

```

RLAB(1)='Cuttings'
RLAB(2)='Spallings'
RLAB(3)='Blowout'
RLAB(4)='Cuttings Volume'
RLAB(5)='Spallings Volume'
RLAB(6)='Blowout Volume'
RLAB(7)='Marker Beds'
RLAB(8)='Dewey Lakes'
RLAB(9)='Surface'
RLAB(10)='Cutting+Spalling+Blowout'
RLAB(11)='Total To Culebra-D'
RLAB(12)='Total From Culebra-D'
RLAB(13)='Total To Culebra-C'
RLAB(14)='Total From Culebra-C'
RLAB(15)='Total To Culebra'
RLAB(16)='Total From Culebra'
RLAB(17)='Total'
C*****READ HEADER RECORDS TO CCDF OUTPUT FILE
C*****READ TITLE FROM MISC INPUT FILE
      READ(14,2001) TITLEP
      WRITE(20,2001) TITLEP
C*****READ NUMBER OF OBSERVATIONS, NUMBER OF FUTURES PER OBS,
C*****TOTAL NUMBER OF RESULTS, NUMBER OF BASE RESULTS, NUMBER OF SPECIES,
C*****NUMBER OF BINS PER CCDF
      READ(14,2002) NOBS, NTH, NRES, NRESO, NRESB, NSPC, MAXDUM
      WRITE(20,2002) NOBS, NTH, NRES, NRESO, NRESB, NSPC, MAXDUM
C*****READ RESULT LABELS
      DO 2000 IRES=0,NRES
        READ(14,2001) RLAB(IRES)
        WRITE(20,2001) RLAB(IRES)
      2000 CONTINUE
C*****FORMAT STATEMENTS
2001 FORMAT(A)
2002 FORMAT(10I8)
      FACTOR=-1.0
      WRITE(*,*) 'ENTER SCALING FACTOR (>0)'
      READ(*,*) FACTOR
      IF(FACTOR.LE.0.) STOP 'STOP: REQUIRE POSITIVE FACTOR'
      DO LOOP=1,2
C*****ACCUMULATE RESULT DISTRIBUTIONS
      DO 4000 IRES=0,NRES
C*****READ RESULT DISTRIBUTION SUMMARY AND CCDF INFO TO FILE

```

```

        READ(14,1001) IOBS, IDUMMY, RMEAN(IRES), PNZERO(IRES),
1          PEAK(IRES), PPEAK(IRES), RSCMIN(IRES)
        WRITE(20,201) IOBS, IDUMMY, RMEAN(IRES), PNZERO(IRES),
1          PEAK(IRES), PPEAK(IRES), RSCMIN(IRES)
        READ(14,1002) (VAL(IBIN), IBIN=1, MAXBIN)
        WRITE(20,202) (VAL(IBIN)/FACTOR, IBIN=1, MAXBIN)
        READ(14,1002) (CUMPRB(IBIN), IBIN=1, MAXBIN)
        WRITE(20,202) (CUMPRB(IBIN), IBIN=1, MAXBIN)
4000    CONTINUE
        ENDDO
        STOP
C*****FORMAT STATEMENTS
1001  FORMAT(2I5,100E10.3)
1002  FORMAT(100E10.3)
201   FORMAT(2I5,1P100E10.3)
202   FORMAT(1P100E10.3)
        END

```

OUTPUT FROM THE DIFFERENCE PROGRAM COMPARING THE CMS AND LINEARITY TEST OUTPUT FILES

Number of difference sections found: 0

Number of difference records found: 0

```

DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=$2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]CCGF DIFF
$2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]CCGF_T2_PA96.OUT;1-
$2$DKB400:[ROOT.HJCHMEL.DOUBLE_R]CCGF_T2_PA96.NEW;1

```

APPENDIX A6 LHS COMPUTER CODE EVALUATION

The PA model is designed to generate estimates of the cumulative normalized release from the repository over a 10,000 year period after closure. Estimates of the releases include subjective uncertainties in the estimates of model parameters, and stochastic uncertainty in the modeling of future processes and events that may affect the repository. Latin Hypercube Sampling (LHS) of uncertain model input parameters addresses the subjective uncertainty surrounding the correct value to use for the PA model parameters. Stochastic uncertainty is addressed within the CCDFGF code as discussed in Appendix A5 for this TSD.

LHS is adopted *in lieu* of a pure Monte Carlo sampling approach to generate efficient estimates of the mean CCDF. LHS ensures selection of random samples from across the entire range covered by the parameter distributions. In a pure Monte Carlo approach, each value for each input parameter is sampled

independently from the appropriate distribution. The LHS method first divides the range of the parameter distribution into strata, defined as intervals of equal probability. An interval is selected, then a random sample is drawn from the selected interval of the distribution.

The effect of this constrained randomization is to ensure a more uniform spread of sampled values over the entire range of the parameter distribution than might be obtained by simple Monte Carlo sampling. If Monte Carlo were used with small sample sizes, it is unlikely that values would be selected from all regions of the parameter distribution. For small sample sizes, the LHS procedure provides a more efficient sampling technique for estimating the mean CCDF.

Much of the information on which the EPA review was based is contained in the QA Packages for 13 PA Codes (Docket: A-93-02, II-G-03, Volume 8). Volume 8 contains the following documents:

UM - Users Manual for LHS Version 2.41, Version 1.00

RD&VVP - Requirements Document & Verification and Validation Plan - Version 1.00 for LHS (Version 2.40)

VD - Validation Document, Version 1.00 for LHS (Version 2.40)

ID - Implementation Document - Version 1.00 for LHS (Version 2.41)

In the ensuing discussion these documents will be referred to by their generic title (i.e., User's Manual) or their generic title abbreviation (i.e., UM). The detailed titles and docket references will not be repeated.

EPA REVIEW

a) **Any compliance application shall include:**

a.1) A description of the conceptual models and scenario construction used to support any compliance application.

The objective of the LHS approach is to provide a measure of the sampling uncertainty associated with the normalized releases estimated by the model. Measures of the sampling variability of the estimated values are required in order to reflect uncertainty in the comparison of the estimated summary CCDF curve to the requirements of 40 CFR 194 and 40 CFR 191.13(a). The requirements of §194.34(f) are summarized as follows.

Any compliance application shall provide information which demonstrates that there is at least a 95 percent level of statistical confidence that the mean of the population of CCDFs meets the containment requirement of §191.13 ...

The level of statistical confidence is determined by the variability in the estimated mean CCDF due to subjective parameter uncertainty.

Important input parameters in the PA are assigned a univariate probability distribution to reflect the uncertainty in the value of the parameter. This provides a unique marginal probability distribution for each LHS parameter. The univariate parameter distributions are described in Appendix PAR (Docket: A-93-02, II-G-1, Volume XI), in Chapter 6 of the CCA (Docket: A-93-02, II-G-1, Volume I), and in User's Manual for LHS. Additional information is provided in Iman and Shortencarier 1984 (Docket: A-93-02, II-G-1, Ref. #327).

The LHS program is also capable of inducing pairwise correlations between the sampled parameter values where correlations are desired. This feature is used sparingly in the CCA. See Section c.6 below for additional information on parameter correlations.

a.2) A description of plausible alternative conceptual model(s) seriously considered but not used to support such application, and an explanation of the reason(s) why such model(s) was not deemed to accurately portray performance of the disposal system.

The LHS sampling procedure operates at two levels. At the first level, 100 equiprobable intervals are created for each input parameter included in the LHS procedure. A random sample is selected from each interval. At the second level of the LHS procedure employed by DOE, the sample values from the first level are arranged into a matrix with values for each of the 57 parameters that will be used in each of the 100 runs. This second level of LHS, called *restricted pairing*, is designed to control unwanted correlations between selected pairs of parameters that may arise by chance if a truly random arrangement were used for this matrix. The rearrangement is done for all parameters, not only the parameters which are assigned to have non-zero correlations.

The LHS program treats each parameter independently, but permits user-specified correlations to be imposed between specified pairs of parameters after the LHS sample is selected. This option is not necessary for traditional LHS analysis and is applied sparingly in the current CCA calculations. The CCA LHS methodology is a constrained LHS method in which unwanted pair-wise correlations are

suppressed (i.e., purposely set to 0). Plausible alternative conceptual models include the use of simple Monte Carlo sampling methods and the use of LHS methods without the restricted pairings option to control correlations.

Efforts to eliminate *spurious* correlations—those that would naturally occur in both unrestricted LHS and pure Monte Carlo methods—serves to decrease the variability of the estimated mean. The precision of the LHS estimate of the mean using restricted pairings may be over-estimated, as compared with pure Monte Carlo Sampling or unrestricted LHS. However, the magnitude of this undesirable effect decreases with increasing sample size. LHS sampling differs from Monte Carlo sampling because it involves sampling without replacement, whereas Monte Carlo sampling involves sampling with replacement. For large sample sizes the difference between sampling with or without replacement is small. Using sample sizes as large as 100 should reduce the effect to acceptable levels.

a.3) Documentation that:

a.3.i) Conceptual models and scenarios reasonably represent possible future states of the disposal system

Unlike other PA models, the LHS program does not model physical phenomena nor does it solve equations that model physical processes. Its principal role in the PA is to generate samples from probability distributions that reasonably represent value of the input parameters required to run the PA model. The list of 57 uncertain parameters selected for inclusion in the LHS procedure is included in Appendix PAR (*ibid.*). The list does not include several important random variables which are unique to the CCDFGF program. The variables generated in the CCDFGF code reflect stochastic uncertainty rather than subjective uncertainty.

Evaluation of the appropriateness of each parameter distribution is covered in the Technical Support Document for Section 194.23: Parameter Justification Report (Docket: A-93-02, III-B-14). This Appendix concentrates on the correct use of the probability distributions assigned elsewhere in the model (*e.g.*, Appendix PAR).

a.3.ii) mathematical models incorporate equations and boundary conditions which reasonably represent the mathematical formulation of the conceptual models.

The mathematical formulation for stochastic and parameter uncertainty is discussed formally in Helton (1996). The mathematical analysis presented in that paper details several possible simulation/integration schemes for obtaining the unconditional mean CCDF for PA.

A pure Monte Carlo simulation approach is used for the stochastic variables. A conditional CCDF is generated by the CCDFGF simulation model for each LHS vector of parameter values. The LHS procedure is designed so that the conditional CCDFs are all equally likely. Hence, it is appropriate to combine the conditional CCDFs into a single unconditional CCDF using equal weights for the CCDF associated with each LHS vector.

Although the general mathematical approach to sampling of parameters is described briefly in Chapter 6 of the CCA (*op. cit.*), the User's Manual for LHS (*op. cit.*), and Appendix PAR (*op. cit.*), no detailed discussion of the Latin Hypercube Sampling (LHS) procedure is included in the CCA. The User's Manual contains a brief discussion of the advantages of this approach. Previous PAs addressed this issue in the main document. A summary of the mathematics is presented in the remainder of this section.

A typical forecasting model for a scalar quantity z given a vector of input parameters is

$$z = g(\mathbf{x}) + e,$$

where the arguments of the deterministic forecasting function g are contained in parameter vector \mathbf{x} , and the random variable e represents forecasting error. If the parameter vector \mathbf{x} is known and the error term has expectation zero, then the scalar value $g(\mathbf{x})$ is the appropriate forecast for z .

Let the notation $E(A|B)$ denote conditional expectation of random variable A , given a specific selected value of the random variable B .

If the parameter vector \mathbf{x} has been assigned a probability distribution, the conditional expectation is used to forecast z . Given any fixed vector value for \mathbf{x} , this forecast is

$$E(z|\mathbf{x}) = g(\mathbf{x}).$$

In the CCA, a multivariate probability distribution function $f(\mathbf{x})$ has been developed to describe the uncertainties in the parameter vector \mathbf{x} . This multivariate distribution for \mathbf{x} is specified by applying the 57 univariate marginal distributions and three selected pair-wise correlations, as developed in Appendix PAR.

In general, the unconditional expectation (forecast) of z is obtained by averaging the conditional expectation over all possible values of \mathbf{x} . The unconditional expectation of z is a weighted average of various $g(\mathbf{x})$ values, with $f(\mathbf{x})$ providing

the appropriate weights:

$$E(z) = E[E(z|\mathbf{x})] = \int \mathbf{x} g(\mathbf{x}) f(\mathbf{x}) d\mathbf{x}$$

The required integral is extremely difficult to evaluate mathematically, however. The LHS method is one Monte Carlo approach to approximating a value for this integral.

a.3.iii) numerical models provide numerical schemes which enable the mathematical models to obtain stable solutions.

As noted in the User's Manual for LHS, the minimum number of sample vectors required to assure representative sampling is roughly 4/3 times the number of parameters sampled. Based on this argument, DOE uses a set of three independent replicates, each of size 100, to demonstrate that the PA model reaches stable solutions. Each replicate uses a different LHS sample of parameter values. Only small differences were noted among the three replicates, indicating that it is not necessary to use higher sample sizes.

a.3.iv) computer models accurately implement the numerical models; i.e., computer codes are free of coding errors and produce stable solutions.

Numerical models for the implementation of the LHS methods are defined in Iman and Shortencarier 1984 (*op cit.*). A summary of the numerical approach is included in the User's Manual. The LHS Fortran code for implementing the numerical model is listed in the Implementation Document. The correctness of the implementation is tested by the tests proposed in the Requirements Documents & Verification and Validation Plan. The results of these tests obtained by DOE are presented in the Validation Document. An EPA review of the validation tests for the LHS code is discussed in Section b.1.v(11) of this appendix.

a.3.v) Conceptual models have undergone peer review according to §194.27

The conceptual model for LHS program is not addressed in Chapter 6 of the CCA. Brief descriptions are found in the User's Manual and Iman and Shortencarier 1984 (*op. cit.*). No Peer Review of the LHS procedures was conducted, as this program does not model future events and process in the repository.

b) Computer codes used to support any compliance application shall be documented in a manner that complies with the requirements of ASME NQA-2a-1990 addenda, part 2.7, to ASME NQA-2-1989 edition.

(Incorporation by reference as specified in § 194.5)

A technical evaluation of the adequacy of the CCA PA QA documents is summarized below.

- *Requirements Document/Verification and Validation Plan*

Functional requirements are listed in the Requirements Document & Verification and Validation Plan (RD/VVP) for LHS. The requirements are that the program correctly implements the LHS procedure, correctly generates the probability distributions assigned to the parameters, properly uses the information contained in the input data sets, and generates a sample with the proper user-specified rank correlations, if this option is selected.

The test plan presented in the VVP provides additional information on these functional requirements related to the correct implementation of the LHS code. Additional static tests are presented, including a coverage analysis. Ten functional tests are presented. The first four tests concern the correct operation of the program in the areas described above. All 10 tests were run on previous versions of the LHS code. Output files from the current version are compared with corresponding files produced by earlier versions of the code.

- *Implementation Document*

The Implementation Document for the LHS program contains over 10,000 lines of FORTRAN code, encompassing approximately 70 subroutines and user-defined functions. This code was used to compile the executable, LHS_PA96.EXE, used for the CCA.

- *User's Manual*

The User's Manual contains a brief discussion of the techniques and advantages of the LHS approach. The manual describes the input and output files, and gives examples of the calculations for a simplified LHS problem.

- *Validation Document*

The Validation Document reports the results of static analyses on the LHS code. The static analysis was completed using the DEC-supplied source code analyzers. The coverage analysis reported that there are 30 LHS modules not called in the coverage test cases. These routines are all used with LHS options not used for the WIPP PA analysis.

The VD also reports the results of the ten tests performed for the LHS code. The tests were run using command script files (.COM) to define the working directory, source for executables, and necessary input files for each test. Output files are written to [.OUT] output and [.DBG] debug subdirectories. The original scripts for the LHS tests were prepared for the CCA-CMS. As part of the review of the VD, all ten tests were rerun and results compared to those reported in the CCA. Attachment 1 of the appendix provides file listings for the tests reconstructed by EPA. The first four tests concern the correct operation of the program in the areas described above. The final six tests determine whether the program recognizes erroneous data in the input files, and provides appropriate error messages. No output files are generated by these tests other than the file containing the error message.

The command LIBCCGF was used to direct the current CCA-CMS pointer to the CCGF library, prior to using the CSE and CFE commands to locate and fetch the required .COM script and .INP input files for the tests. The CSE command was used to locate the .COM files used for running the original LHS tests for the CCA. These files were then fetched using the CFE command. The directory names referenced in the .COM script for each test were modified as needed to run the various tests using the PA96 executable in the CCA-CMS. Note, the required .INP files had been modified to include CCA-CMS documentation lines at the end of each file. This necessitated removing these lines from the end of each file to obtain proper execution of the LHS program.

The tests were conducted in numerical order. The first 4 tests use valid input files and are expected to run to completion with no error messages. It was also expected that the output files for each test would match those in the CMS. The final six tests use input files with erroneous input data—i.e., to test the error handling capability of the code. It was expected that error messages would be encountered when running these tests. The scripts and input files used for each test are shown in the listing at the end of this appendix. Output files and the results of the DIFFERENCE program—comparing the old and new files—are also listed there.

The following steps were completed to review the LHS tests:

Created working directory [-.LHS.TEST] and moved the files to that directory.

Created .DBG and .OUT subdirectories to hold output files for the ten tests.

Reconstruction of Test 1:

Used CFE to fetch the .INP file for Test 1. Removed last few records. Modified

the .COM script to run Test 1. Ran the LHS Version 2.40 executable. No error messages were noted on execution. Changed to the .OUT directory. Fetched the Test 1 .OUT file from the CCA-CMS. Used the DIF command to compare the two output file. No differences were found.

Reconstruction of Test 2:

Used CFE to fetch the .INP file for Test 2. Removed last few records. Modified the .COM script to run Test 2. Ran the LHS Version 2.40 executable. No error messages were noted on execution. Changed to the .OUT directory. Fetched the Test 2 .OUT file from the CCA-CMS. Used the DIF command to compare the two output files. No differences were found.

Reconstruction of Test 3:

Used CFE to fetch the .INP file for Test 3. Removed last few records. Modified the .COM script to run Test 3. Ran the LHS Version 2.40 executable. No error messages were noted on execution. Changed to the .OUT directory. Fetched the Test 3 .OUT file from the CCA-CMS. Used the DIF command to compare the two output files. Major differences were found between the two files. Determined that the .OUT file for Test 3 in the CCA-CMS was an older version of the Test 3 output file, created on 8/23/95. Apparently, an output file from an earlier run of the test was inadvertently selected for incorporation into the CCA-CMS when it was built. Even though the output file failed the difference test, further inspection indicated that the test had run properly.

Reconstruction of Test 4:

Used CFE to fetch the .INP file for Test 4. Removed last few records. Modified the .COM script to run Test 4. Ran the LHS Version 2.40 executable. No error messages were noted on execution. Changed to the .OUT directory. Fetched the Test 4 .OUT file from the CCA-CMS. Used the DIF command to compare the two output files. No differences were found.

Reconstruction of Test 5:

Used CFE to fetch the .INP file for Test 5. Removed last few records. Modified the .COM script to run Test 5. Ran the LHS Version 2.40 executable. As expected, error messages were noted on execution. Moved to the output directory, checked output file which contained the appropriate error message.

Reconstruction of Test 6:

Used CFE to fetch the .INP file for Test 6. Removed last few records. Modified the .COM script to run Test 6. Ran the LHS Version 2.40 executable. As expected, error messages were noted on execution. Moved to the output directory, checked output file which contained the appropriate error message.

Reconstruction of Test 7:

Used CFE to fetch the .INP file for Test 7. Removed last few records. Modified the .COM script to run Test 7. Ran the LHS Version 2.40 executable. As expected, error messages were noted on execution. Moved to the output directory, checked output file which contained the appropriate error message.

Reconstruction of Test 8:

Used CFE to fetch the .INP file for Test 8. Removed last few records. Modified the .COM script to run Test 8. Ran the LHS Version 2.40 executable. As expected, error messages were noted on execution. Moved to the output directory, checked output file which contained the appropriate error message.

Reconstruction of Test 9:

Used CFE to fetch the .INP file for Test 9. Removed last few records. Modified the .COM script to run Test 9. Ran the LHS Version 2.40 executable. As expected, error messages were noted on execution. Moved to the output directory, checked output file which contained the appropriate error message.

Reconstruction of Test 10:

Used CFE to fetch the .INP file for Test 10. Removed last few records. Modified the .COM script to run Test 10. Ran the LHS Version 2.40 executable. As expected, error messages were noted on execution. Moved to the output directory, checked output file. It contained the appropriate error message.

c) Documentation of all models and computer codes are included as part of any compliance application performance assessment calculation shall be provided. Such documentation shall include, but not be limited to:

c.1) Descriptions of the theoretical backgrounds of each model and the method of analysis or assessment,

The theoretical background for the LHS code is found in the User's Manual and in

Iman and Shortencarier 1984 (*op. cit.*).

c.2) General descriptions of the models; discussions of the limits of applicability of each model; detailed instructions for executing the computer codes, including hardware and software requirements, input and output formats with explanations of each input and output variable and parameter (e.g., parameter name and units); listings of input and output files from a sample computer run; and reports on code verification, benchmarking, validation, and quality assurance procedures.

Capabilities and limitations are discussed on page 12 of the User's Manual. Detailed instructions for executing the code are found in the User's Manual (pp. 12 - 50), and in the VVD where execution instructions are included as part of the testing. A brief discussion of Hardware Requirements is included in the VD. The Implementation Document for LHS provides a code listing and build script. Software requirements for implementing the coverage analysis are also included in the VVD. Input and output formats are discussed in the User's Manual for LHS (pp. 7-50). Sample pages are printed in the Appendices to the User's Manual.

The input parameters to the LHS program consist of the coefficients which specify probability distributions for each of the 57 PA model parameters included in the LHS procedure. Physical parameters used in the model have been assigned probability distributions based either on available data or the subjective opinion of experts. Many types of probability distributions are used to describe the uncertainty in the WIPP PA model input parameters.

The families of probability distributions selected for the PA model input parameters include the uniform, loguniform, triangular, Student's t, cumulative, logcumulative and delta distributions. All but the delta distribution are defined for variables that can take a continuous range of values. The delta distribution is used for parameters which can take only a discrete set of values. The uniform, loguniform, and triangular distributions are appropriate for parameters that are assumed to lie in an interval between two known endpoints. In the LHS code, the Student's t distributions is defined to extend only to the 1st and 99th percentiles, rather than to continue indefinitely past these extremes.

Some distributions do not belong to a known family of distributions. The cumulative or *constructed* distribution is created directly from the observed data by forming the observed cumulative distribution function. The logcumulative distribution uses the same method applied to the logarithms of the parameter

values. Appendix PAR (*op. cit.*) also introduces the normal and lognormal distributions, however it appears no parameters were assigned distributions of these types.

The LHS program is capable of inducing pair-wise correlations between the sampled parameter values where correlations are desired. This feature is used sparingly in the CCA. Current LHS procedures treat almost all pairs of input variables as uncorrelated. This is a generally accepted statistical practice. Correlations were assigned to three pairs of parameters. These pairs are examined in Section c.6 of this appendix.

Mathematical definitions of each input and output variable are provided in Iman and Shortencarier 1984 (*op. cit.*). Additional information is included in the User's Manual for LHS. Explanations of the source for each parameter distribution are described in Appendix PAR references. Additional information is available on the Data Entry Forms (Form 464).

The Validation Document reports the results of ten tests performed to validate the LHS code. Results of the tests indicate all requirements listed in the VVP were satisfied.

c.3) Detailed descriptions of the structure of computer codes and complete listings of the source codes.

Iman and Shortencarier 1984 (*op. cit.*) contains a description of the LHS code. The Implementation Document for the LHS program contains a listing of FORTRAN code, encompassing approximately 70 subroutines and user-defined functions. This code was used to compile the executable, LHS_PA96.EXE, used for the CCA.

c.4) Detailed descriptions of data collection procedures, sources of data, data reduction and analysis, and code input parameter development.

This consideration is not applicable to the LHS code. No parameters are used by the LHS code other than the required sample size and the coefficients of the probability distributions for the WIPP model parameters.

Parameters and their distributions are discussed in the Technical Support Document for Section 194.23: Parameter Report (Docket: A-93-02, III-B-12) and the Technical Support Document for Section 194.23: Parameter Justification Report (Docket: A-93-02, III-B-14).

A description of input parameter development is not applicable to the LHS code.

No data are used by the code other than the sample size and the parameters of the probability distributions for the WIPP model parameters.

c.5) Any necessary licenses

This consideration is not applicable to the LHS code. No licenses are required.

c.6) An explanation of the manner in which models and computer codes incorporate the effects of parameter correlation.

DOE samples 57 uncertain parameters in LHS. Current LHS procedures treat most input variables as uncorrelated. This is a generally accepted statistical practice. The general methods for addressing correlation are included in Iman and Shortencarier 1984 (*op. cit.*).

Several variables are identified in Appendix PAR (p. PAR-12) with strong correlations. In BRAGFLO, rock compressibility and intrinsic permeability in MB139 are assigned a -0.99 correlation. The same highly negative correlation is used for the same parameters in the Salado halite.

The other significant example of parameter correlation actually used in the current CCA involves the Castile brine reservoir region, where the rock compressibility and intrinsic permeability are assigned a correlation of -0.75.

d) The Administrator or the Administrator's authorized representative may verify results of computer simulations used to support any compliance application by performing independent simulations. Data files, source codes, executable versions of computer software for each model, other material or information needed to permit the Administrator or the Administrator's authorized representative to perform independent simulations, and access to necessary hardware to perform such simulations, shall be provided within 30 calendar days of a request by the Administrator or the Administrator's authorized representative.

Independent simulation of the tests presented in the VVD was relatively straight-forward. The replication of these tests are discussed in Section b.1.v(12) above.

Input data files for the LHS code, the LHS_PA96 source code, and the LHS_PA96 executable are available in the CCA-CMS. Tests 1 through 10 listed in the VVD were run with this version of the executable, as discussed in Section b.1.v(13).

Access to the Sandia VAX hardware is available through internet Telnet

connections, after obtaining proper authorization.

REFERENCES

Helton, J.C. 1996. *Probability, Conditional Probability, and Complementary Cumulative Distribution Functions for Radioactive Waste Disposal*. SAND95-2571. Sandia National Laboratories, Albuquerque NM. March 1996.

See Appendix B for listing of docketed references.

ATTACHMENT 1 - FILE LISTINGS FOR LHS TESTS RECONSTRUCTED BY EPA

.COM FILE FOR RUNNING LHS TESTS

```
$! -----
$! MODULE:   LHS2_RUN_PCA.COM
$! PURPOSE:  RUN TEST CASES FOR LHS USING THE PA96 PRODUCTION VERSION OF
$!           LHS VERSION 2.40
$! PARAMETERS:  NONE
$! AUTHOR:    H. J. CHMELYNSKI
$! DATE:     02/03/97
$! -----
$! Setup for testing
$ SET NOON
$ TESTDIR:= "EPA:[ROOT.HJCHMEL.LHS2.TEST]"
$ OUTDIR  := "EPA:[ROOT.HJCHMEL.LHS2.TEST.OUT]"
$ DBGDIR  := "EPA:[ROOT.HJCHMEL.LHS2.TEST.DBG]"
$ EXE_SRC := $WP$PRODROOT:[LHS.EXE]LHS_PA96.EXE
$! -----
$! Set number of last test case and initialize counter
$ NCASE = 10
$ STARTCASE = 0
$ P1 = STARTCASE
$! -----
$! Execute all test cases
$ EXETEST:
$ P1 = P1 + 1
$! Define file names
$ DEFINE LHS2_UIF$INPUT   'TESTDIR'LHS2_T'P1'.INP
$ DEFINE LHS2_OUT$OUTPUT 'OUTDIR'LHS2_T'P1'.OUT
$ DEFINE LHS2_DBG$OUTPUT 'DBGDIR'LHS2_T'P1'_DBG.OUT
$ DEFINE LHS2_NO2$SCRTCH FOR002.DAT
$ DEFINE LHS2_NO3$SCRTCH FOR003.DAT
```

```

$ DEFINE LHS2_NO4$SCRTCH FOR004.DAT
$ DEFINE LHS2_NO7$SCRTCH FOR007.DAT
$ DEFINE LHS2_NO8$SCRTCH FOR008.DAT
$ DEFINE LHS2_NO9$SCRTCH FOR009.DAT
$! -----
$! Execute test case P1
$ EXE_SRC
$! Go to start of execute loop for next case if not all done
$ IF P1 .LT. NCASE THEN GOTO EXETEST
$! -----
$! Inform user where files are
$ write sys$output " Test cases Completed"
$ write sys$output " Output files are in directory [LHS2.TEST.OUT]"
$ write sys$output " Debug files are in directory [LHS2.TEST.DBG]"
$! -----
$ EXIT
$! CMS REPLACEMENT HISTORY, Element LHS2_TEST.COM
$! *7      12-FEB-1996 10:04:33 LNSMITH "TEST CASE SUITE MODIFIED."
$! *6       6-FEB-1996 14:32:42 LNSMITH "REVISION TO .COM FILE NECESSARY."
$! *5      19-OCT-1995 08:29:24 LNSMITH "REMOVED EXTRANEIOUS COMMENT LINES."
$! *4      28-SEP-1995 12:14:07 LNSMITH "REMOVED BLANK LINES IN FILE."
$! *3       5-SEP-1995 15:33:31 LNSMITH "ADDED ADDITIONAL TEST CASE."
$! *2      28-AUG-1995 14:33:12 LNSMITH "MODIFIED EXECUTABLE FILE NAME."
$! *1      28-AUG-1995 11:15:41 LNSMITH "INITIAL LOAD."
$! CMS REPLACEMENT HISTORY, Element LHS2_TEST.COM
OUTPUT OF DIFFERENCE COMMANDS FROM LHS TESTS
OUTPUT OF DIFFERENCE COMMAND FOR TEST 1
Number of difference sections found: 0
Number of difference records found: 0
DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=$2$DKB400:[ROOT.HJCHMEL.LHS2.TEST.OUT]LHS2
    $2$DKB400:[ROOT.HJCHMEL.LHS2.TEST.OUT]LHS2_T1.OUT;2-
    $2$DKB400:[ROOT.HJCHMEL.LHS2.TEST.OUT]LHS2_T1.OUT;1
OUTPUT OF DIFFERENCE COMMAND FOR TEST 2
Number of difference sections found: 0
Number of difference records found: 0
DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=$2$DKB400:[ROOT.HJCHMEL.LHS2.TEST.OUT]LHS2
    $2$DKB400:[ROOT.HJCHMEL.LHS2.TEST.OUT]LHS2_T2.OUT;2-
    $2$DKB400:[ROOT.HJCHMEL.LHS2.TEST.OUT]LHS2_T2.OUT;1
OUTPUT OF DIFFERENCE COMMAND FOR TEST 3
< FILE TOO LARGE TO PRINT.  MANY DIFFERENCE FOUND.  SEE TEXT. >
OUTPUT OF DIFFERENCE COMMAND FOR TEST 4
Number of difference sections found: 0

```

Number of difference records found: 0

DIFFERENCES /IGNORE=()/MERGED=1/OUTPUT=\$2\$DKB400:[ROOT.HJCHMEL.LHS2.TEST.OUT]LHS2
\$2\$DKB400:[ROOT.HJCHMEL.LHS2.TEST.OUT]LHS2_T4.OUT;1-
\$2\$DKB400:[ROOT.HJCHMEL.LHS2.TEST.OUT]LHS2_T4.OUT;2

INPUT FILE FOR LHS TEST 1

TITLE CMS Test Input File for the LHS Code Test 1

NOBS	75		
RANDOM SEED	933090934		
NORMAL		NORMMAT1	NORMPRP1
0.00000E+00	2.00000E-01		
NORMAL		NORMMAT2	NORMPRP2
5.77000E+02	1.04200E+03		
NORMAL		NORMMAT3	NORMPRP3
-3.67370E-02	8.32640E-02		
LOGNORMAL		LOGNMAT1	LOGNPRP1
1.00000E-02	2.13000E+00		
LOGNORMAL		LOGNMAT2	LOGNPRP2
1.00000E-03	3.50000E+02		
LOGNORMAL		LOGNMAT3	LOGNPRP3
1.00000E-04	5.25000E+04		
UNIFORM		UNIFMAT1	UNIFPRP1
-5.00000E-01	5.00000E-01		
UNIFORM		UNIFMAT2	UNIFPRP2
0.00000E+00	1.00000E+00		
UNIFORM		UNIFMAT3	UNIFPRP3
1.25000E+01	5.00000E+02		
LOGUNIFORM		LOGUMAT1	LOGUPRP1
1.00000E-17	1.00000E-11		
LOGUNIFORM		LOGUMAT2	LOGUPRP2
1.00000E-06	1.00000E+03		
LOGUNIFORM		LOGUMAT3	LOGUPRP3
5.60000E+13	5.60000E+15		
USER DISTRIBUTION (CUMULATIVE)		CUMMAT1	CUMPRP1
4	SPECIFIED	CONTINUOUS	
-8.00000E+00	0.10000		
-6.57000E+00	0.80000		
-4.77000E+00	0.10000		
-2.00000E+00	0.00000		
USER DISTRIBUTION (CUMULATIVE)		CUMMAT2	CUMPRP2
4	SPECIFIED	CONTINUOUS	
-1.25000E+01	0.15000		
-9.00000E+00	0.45000		

-6.51000E+00	0.40000				
-5.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT3	CUMPRP3	
4	SPECIFIED		CONTINUOUS		
-8.60000E+00	0.10000				
-8.00000E+00	0.60000				
-3.25000E+00	0.30000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(DATA)		DATAMAT1	DATAPRP1	
21	EQUAL		CONTINUOUS		
5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			
USER DISTRIBUTION	(DATA)		DATAMAT2	DATAPRP2	
9	EQUAL		CONTINUOUS		
2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01
7.94300E+01	8.90880E+01	1.03800E+02			
USER DISTRIBUTION	(DATA)		DATAMAT3	DATAPRP3	
12	EQUAL		CONTINUOUS		
1.22250E+00	9.30000E+00	1.09000E+01	1.38500E+01	2.74330E+01	3.46500E+01
4.61600E+01	5.01800E+01	6.15170E+01	7.38000E+01	8.78400E+01	9.49600E+01
USER DISTRIBUTION	(DELTA)		DELTMAT1	DELTPRP1	
14	SPECIFIED		DISCRETE		
5.08000E-02	0.07143				
1.01600E-01	0.07143				
1.52400E-01	0.07143				
1.93680E-01	0.07143				
2.19080E-01	0.07143				
2.28600E-01	0.07143				
2.50830E-01	0.07143				
2.79400E-01	0.07143				
3.04800E-01	0.07143				
3.49250E-01	0.07143				
3.81000E-01	0.07143				
4.44500E-01	0.07143				
5.58800E-01	0.07143				
6.09600E-01	0.07141				
USER DISTRIBUTION	(DELTA)		DELTMAT2	DELTPRP2	
4	SPECIFIED		DISCRETE		
1.00000E+00	0.30000				
2.00000E+00	0.15000				

3.00000E+00	0.20000		
4.00000E+00	0.35000		
USER DISTRIBUTION	(DELTA)	DELTMAT3	DELTPRP3
6	SPECIFIED	DISCRETE	
-1.00000E+01	0.13000		
2.00000E+00	0.13000		
8.00000E+00	0.26000		
2.30000E+01	0.15000		
3.40000E+01	0.15000		
4.00000E+01	0.18000		

CORRELATION MATRIX

7		
1	3	0.999
2	5	0.950
4	6	0.800
5	2	0.950
7	8	0.650
7	9	0.650
8	9	0.650

OUTPUT CORR HIST DATA

INPUT FILE FOR LHS TEST 2

TITLE CMS Test Input File for the LHS Code Test 2

NOBS	200		
RANDOM SEED	933090934		
NORMAL	GLOBAL	DISPPERC	
0.00000E+00	2.00000E-01		
NORMAL	WEP203	QRF_M2CS	
5.77000E+02	1.04200E+03		
NORMAL	WEP203	QRF_M2TC	
-3.67370E-02	8.32640E-02		
LOGNORMAL	TESTMAT1	TESTPRP1	
.01	2.13		
LOGNORMAL	TESTMAT2	TESTPRP2	
.001	3.45		
LOGNORMAL	TESTMAT3	TESTPRP3	
.0001	5.25		
UNIFORM	CANISTER	EFFCAREA	
-5.00000E-01	5.00000E-01		
UNIFORM	CANISTER	BACFRC	
0.00000E+00	1.00000E+00		
UNIFORM	PU	KDFE	
1.25000E+01	5.00000E+02		

LOGUNIFORM		GCERAMIC	CORATEOX		
1.00000E-17		1.00000E-11			
LOGUNIFORM		CANISTER	EFFDAREA		
1.00000E-06		1.00000E+03			
LOGUNIFORM		IN825	CORATEOX		
5.60000E+13		5.60000E+15			
USER DISTRIBUTION	(CUMULATIVE)		NP		LOGSOLMS
4	SPECIFIED		CONTINUOUS		
-8.00000E+00	0.10000				
-6.57000E+00	0.80000				
-4.77000E+00	0.10000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		PU		LOGSOLMS
4	SPECIFIED		CONTINUOUS		
-1.25000E+01	0.10000				
-9.00000E+00	0.80000				
-6.51000E+00	0.10000				
-5.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		U		LOGSOLMS
4	SPECIFIED		CONTINUOUS		
-8.60000E+00	0.10000				
-8.00000E+00	0.80000				
-3.25000E+00	0.10000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(DATA)		Culebra	Porosity	
21	EQUAL		CONTINUOUS		
5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			
USER DISTRIBUTION	(DATA)		TESTMAT1	TESTPRM1	
9	EQUAL		CONTINUOUS		
2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01
7.94300E+01	8.90880E+01	1.03800E+02			
USER DISTRIBUTION	(DATA)		TESTMAT2	TESTPRM2	
12	EQUAL		CONTINUOUS		
-1.22250E+00	-9.30000E-01	-1.29000E-01	1.38500E-01	9.74330E-01	1.46500E+00
3.61600E+00	6.01800E+00	1.15170E+01	1.38000E+01	1.78400E+01	1.99600E+01
USER DISTRIBUTION	(DELTA)		BOREHOLE	DIAMMOD	
14	SPECIFIED		DISCRETE		
5.08000E-02	0.07143				
1.01600E-01	0.07143				

1.52400E-01 0.07143
 1.93680E-01 0.07143
 2.19080E-01 0.07143
 2.28600E-01 0.07143
 2.50830E-01 0.07143
 2.79400E-01 0.07143
 3.04800E-01 0.07143
 3.49250E-01 0.07143
 3.81000E-01 0.07143
 4.44500E-01 0.07143
 5.58800E-01 0.07143
 6.09600E-01 0.07144

USER DISTRIBUTION (DELTA) DRZ_0 RELP_MOD
 4 SPECIFIED DISCRETE
 1.00000E+00 0.30000
 2.00000E+00 0.15000
 3.00000E+00 0.20000
 4.00000E+00 0.35000

USER DISTRIBUTION (DELTA) S_HALITE GRID_ID
 6 SPECIFIED DISCRETE
 -1.00000E+01 0.13000
 2.00000E+00 0.13000
 8.00000E+00 0.26000
 2.30000E+01 0.15000
 3.40000E+01 0.15000
 4.00000E+01 0.18000

OUTPUT CORR HIST DATA

INPUT FILE FOR LHS TEST 3

TITLE CMS Test Input File for the LHS Code Test 3
 NOBS 75
 RANDOM SEED 933090934
 NORMAL GLOBAL DISPPERC
 5.00000E-02 2.00000E-01
 LOGNORMAL COLLOID CONC
 1.00000E-02 1.00000E+02
 UNIFORM WAS_AREA TAUFAIL
 4.80000E-02 9.60000E+00
 LOGUNIFORM WAS_AREA SPPERM
 1.00000E-17 1.00000E-12
 USER DISTRIBUTION (CUMULATIVE) BOREHOLE OMEGA
 20 SPECIFIED CONTINUOUS
 4.20000E+00 0.00000

4.20000E+00	0.15000
6.30000E+00	0.00000
6.30000E+00	0.50000
8.40000E+00	0.00000
8.40000E+00	0.15000
1.05000E+01	0.00000
1.05000E+01	0.10000
1.26000E+01	0.00000
1.26000E+01	0.05000
1.47000E+01	0.00000
1.47000E+01	0.02000
1.68000E+01	0.00000
1.68000E+01	0.01000
1.88000E+01	0.00000
1.88000E+01	0.01000
2.09000E+01	0.00000
2.09000E+01	0.01000
2.30000E+01	0.00000
2.30000E+01	0.00000

USER DISTRIBUTION (DATA)		CULEBRA POROSITY			
21	EQUAL	CONTINUOUS			
5.80563E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			

USER DISTRIBUTION (DELTA)		BOREHOLE DIAMMOD	
14	SPECIFIED	DISCRETE	
5.08000E-02	0.07143		
1.01600E-01	0.07143		
1.52400E-01	0.07143		
1.93680E-01	0.07143		
2.19080E-01	0.07143		
2.28600E-01	0.07143		
2.50830E-01	0.07143		
2.79400E-01	0.07143		
3.04800E-01	0.07143		
3.49250E-01	0.07143		
3.81000E-01	0.07143		
4.44500E-01	0.07143		
5.58800E-01	0.07143		
6.09600E-01	0.07144		

TRIANGULAR	WAS_AREA	GRATCORI
------------	----------	----------

0.00000E+00	3.20000E-09	6.40000E-07			
STUDENT	S_MB139	POROSITY			
16					
4.00000E-03	5.00000E-03	5.00000E-03	8.00000E-03	1.00000E-02	1.10000E-02
1.30000E-02	1.30000E-02	1.60000E-02	1.60000E-02	1.60000E-02	1.70000E-02
1.80000E-02	1.90000E-02	2.10000E-02	2.70000E-02		
LOGSTUDENT	STULMAT1	STULPRP1			
20					
9.55000E-07	1.03330E-06	1.57400E-06	2.15000E-06	4.20500E-06	8.22250E-06
2.23500E-05	4.29000E-05	7.38500E-05	9.44330E-05	1.46500E-04	3.61600E-04
5.61800E-04	7.65170E-04	9.78000E-04	1.78400E-03	2.79600E-03	5.02500E-03
7.07750E-03	9.52500E-03				

CORRELATION MATRIX

7		
1	3	-0.999
2	5	-0.950
4	6	-0.800
5	2	-0.950
7	8	-0.650
7	9	-0.650
8	9	-0.650

OUTPUT CORR HIST DATA

INPUT FILE FOR LHS TEST 4

TITLE CMS Test Input File for the LHS Code Test 4

NOBS 75

RANDOM SEED 933090934

UNIFORM	UNIFMAT2	UNIFPRP2
0.00000E+00	1.00000E+00	
NORMAL	NORMMAT3	NORMPRP3
-3.67370E-02	8.32640E-02	
LOGNORMAL	LOGNMAT2	LOGNPRP2
1.00000E-03	3.50000E+02	
UNIFORM	UNIFMAT1	UNIFPRP1
-5.00000E-01	5.00000E-01	
USER DISTRIBUTION	(DELTA)	DELTMAT3 DELTPRP3
6	SPECIFIED	DISCRETE
-1.00000E+01	0.13000	
2.00000E+00	0.13000	
8.00000E+00	0.26000	
2.30000E+01	0.15000	
3.40000E+01	0.15000	
4.00000E+01	0.18000	

UNIFORM		UNIFMAT3	UNIFPRP3		
	1.25000E+01	5.00000E+02			
LOGUNIFORM		LOGUMAT1	LOGUPRP1		
	1.00000E-17	1.00000E-11			
USER DISTRIBUTION	(DATA)		DATAMAT2	DATAPRP2	
	9	EQUAL	CONTINUOUS		
	2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01 6.34200E+01
	7.94300E+01	8.90880E+01	1.03800E+02		
NORMAL		NORMMAT1	NORMPRP1		
	0.00000E+00	2.00000E-01			
USER DISTRIBUTION	(DELTA)		DELTMAT1	DELTPRP1	
	14	SPECIFIED	DISCRETE		
	5.08000E-02	0.07143			
	1.01600E-01	0.07143			
	1.52400E-01	0.07143			
	1.93680E-01	0.07143			
	2.19080E-01	0.07143			
	2.28600E-01	0.07143			
	2.50830E-01	0.07143			
	2.79400E-01	0.07143			
	3.04800E-01	0.07143			
	3.49250E-01	0.07143			
	3.81000E-01	0.07143			
	4.44500E-01	0.07143			
	5.58800E-01	0.07143			
	6.09600E-01	0.07141			
LOGUNIFORM		LOGUMAT3	LOGUPRP3		
	5.60000E+13	5.60000E+15			
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT1	CUMPRP1	
	4	SPECIFIED	CONTINUOUS		
	-8.00000E+00	0.10000			
	-6.57000E+00	0.80000			
	-4.77000E+00	0.10000			
	-2.00000E+00	0.00000			
NORMAL		NORMMAT2	NORMPRP2		
	5.77000E+02	1.04200E+03			
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT3	CUMPRP3	
	4	SPECIFIED	CONTINUOUS		
	-8.60000E+00	0.10000			
	-8.00000E+00	0.60000			
	-3.25000E+00	0.30000			
	-2.00000E+00	0.00000			

```

LOGNORMAL          LOGNMAT1  LOGNPRP1
  1.00000E-02    2.13000E+00
USER DISTRIBUTION (DATA)          DATAMAT1  DATAPRP1
  21          EQUAL          CONTINUOUS
  5.80565E-02  9.55000E-02  1.03330E-01  1.07400E-01  1.15000E-01  1.20500E-01
  1.22250E-01  1.23500E-01  1.29000E-01  1.38500E-01  1.44330E-01  1.46500E-01
  1.61600E-01  1.61800E-01  1.65170E-01  1.78000E-01  1.78400E-01  1.79600E-01
  2.02500E-01  2.07750E-01  2.52500E-01

```

```

LOGNORMAL          LOGNMAT3  LOGNPRP3
  1.00000E-04    5.25000E+04
USER DISTRIBUTION (DATA)          DATAMAT3  DATAPRP3
  12          EQUAL          CONTINUOUS
  1.22250E+00  9.30000E+00  1.09000E+01  1.38500E+01  2.74330E+01  3.46500E+01
  4.61600E+01  5.01800E+01  6.15170E+01  7.38000E+01  8.78400E+01  9.49600E+01

```

CORRELATION MATRIX

```

  7
  1  3  0.999
  2  5  0.950
  4  6  0.800
  5  2  0.950
  7  8  0.650
  7  9  0.650
  8  9  0.650

```

```

USER DISTRIBUTION (CUMULATIVE)          CUMMAT2  CUMPRP2
  4          SPECIFIED          CONTINUOUS
  -1.25000E+01  0.15000
  -9.00000E+00  0.45000
  -6.51000E+00  0.40000
  -5.00000E+00  0.00000

```

```

LOGUNIFORM          LOGUMAT2  LOGUPRP2
  1.00000E-06    1.00000E+03
USER DISTRIBUTION (DELTA)          DELTMAT2  DELTPRP2
  4          SPECIFIED          DISCRETE
  1.00000E+00  0.30000
  2.00000E+00  0.15000
  3.00000E+00  0.20000
  4.00000E+00  0.35000

```

OUTPUT CORR HIST DATA

INPUT FILE FOR LHS TEST 5

```

TITLE CMS Test Input File for the LHS Code  Test 5
NOBS          75THIS IS THE NUMBER OF OBSERVATIONS TO GENERATE
RANDOM SEED    933090934

```

NORMAL		NORMMAT1	NORMPRP1	
0.00000E+00	2.00000E-01			
NORMAL		NORMMAT2	NORMPRP2	
5.77000E+02	1.04200E+03			
NORMAL		NORMMAT3	NORMPRP3	
-3.67370E-02	8.32640E-02			
LOGNORMAL		LOGNMAT1	LOGNPRP1	
1.00000E-02	2.13000E+00			
LOGNORMAL		LOGNMAT2	LOGNPRP2	
1.00000E-03	3.50000E+02			
LOGNORMAL		LOGNMAT3	LOGNPRP3	
1.00000E-04	5.25000E+04			
UNIFORM		UNIFMAT1	UNIFPRP1	
-5.00000E-01	5.00000E-01			
UNIFORM		UNIFMAT2	UNIFPRP2	
0.00000E+00	1.00000E+00			
UNIFORM		UNIFMAT3	UNIFPRP3	
1.25000E+01	5.00000E+02			
LOGUNIFORM		LOGUMAT1	LOGUPRP1	
1.00000E-17	1.00000E-11			
LOGUNIFORM		LOGUMAT2	LOGUPRP2	
1.00000E-06	1.00000E+03			
LOGUNIFORM		LOGUMAT3	LOGUPRP3	
5.60000E+13	5.60000E+15			
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT1	CUMPRP1
4	SPECIFIED		CONTINUOUS	
-8.00000E+00	0.10000			
-6.57000E+00	0.80000			
-4.77000E+00	0.10000			
-2.00000E+00	0.00000			
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT2	CUMPRP2
4	SPECIFIED		CONTINUOUS	
-1.25000E+01	0.15000			
-9.00000E+00	0.45000			
-6.51000E+00	0.40000			
-5.00000E+00	0.00000			
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT3	CUMPRP3
4	SPECIFIED		CONTINUOUS	
-8.60000E+00	0.10000			
-8.00000E+00	0.60000			
-3.25000E+00	0.30000			
-2.00000E+00	0.00000			

USER DISTRIBUTION (DATA)			DATAMAT1	DATAPRP1		
21	EQUAL		CONTINUOUS			
5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01	
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01	
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01	
2.02500E-01	2.07750E-01	2.52500E-01				
USER DISTRIBUTION (DATA)			DATAMAT2	DATAPRP2		
9	EQUAL		CONTINUOUS			
2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01	
7.94300E+01	8.90880E+01	1.03800E+02				
USER DISTRIBUTION (DATA)			DATAMAT3	DATAPRP3		
12	EQUAL		CONTINUOUS			
1.22250E+00	9.30000E+00	1.09000E+01	1.38500E+01	2.74330E+01	3.46500E+01	
4.61600E+01	5.01800E+01	6.15170E+01	7.38000E+01	8.78400E+01	9.49600E+01	
USER DISTRIBUTION (DELTA)			DELTMAT1	DELTPRP1		
14	SPECIFIED		DISCRETE			
5.08000E-02	0.07143					
1.01600E-01	0.07143					
1.52400E-01	0.07143					
1.93680E-01	0.07143					
2.19080E-01	0.07143					
2.28600E-01	0.07143					
2.50830E-01	0.07143					
2.79400E-01	0.07143					
3.04800E-01	0.07143					
3.49250E-01	0.07143					
3.81000E-01	0.07143					
4.44500E-01	0.07143					
5.58800E-01	0.07143					
6.09600E-01	0.07141					
USER DISTRIBUTION (DELTA)			DELTMAT2	DELTPRP2		
4	SPECIFIED		DISCRETE			
1.00000E+00	0.30000					
2.00000E+00	0.15000					
3.00000E+00	0.20000					
4.00000E+00	0.35000					
USER DISTRIBUTION (DELTA)			DELTMAT3	DELTPRP3		
6	SPECIFIED		DISCRETE			
-1.00000E+01	0.13000					
2.00000E+00	0.13000					
8.00000E+00	0.26000					
2.30000E+01	0.15000					

3.40000E+01 0.15000

4.00000E+01 0.18000

CORRELATION MATRIX

7

1 3 -0.999

2 5 -0.950

4 6 -0.800

5 2 -0.950

7 8 -0.650

7 9 -0.650

8 9 -0.650

OUTPUT CORR HIST DATA

INPUT FILE FOR LHS TEST 6

TITLE CMS Test Input File for the LHS Code Test 6

NOBS -75

RANDOM SEED 933090934

NORMAL NORMMAT1 NORMPRP1

0.00000E+00 2.00000E-01

NORMAL NORMMAT2 NORMPRP2

5.77000E+02 1.04200E+03

NORMAL NORMMAT3 NORMPRP3

-3.67370E-02 8.32640E-02

LOGNORMAL LOGMAT1 LOGNPRP1

1.00000E-02 2.13000E+00

LOGNORMAL LOGMAT2 LOGNPRP2

1.00000E-03 3.50000E+02

LOGNORMAL LOGMAT3 LOGNPRP3

1.00000E-04 5.25000E+04

UNIFORM UNIFMAT1 UNIFPRP1

-5.00000E-01 5.00000E-01

UNIFORM UNIFMAT2 UNIFPRP2

0.00000E+00 1.00000E+00

UNIFORM UNIFMAT3 UNIFPRP3

1.25000E+01 5.00000E+02

LOGUNIFORM LOGUMAT1 LOGUPRP1

1.00000E-17 1.00000E-11

LOGUNIFORM LOGUMAT2 LOGUPRP2

1.00000E-06 1.00000E+03

LOGUNIFORM LOGUMAT3 LOGUPRP3

5.60000E+13 5.60000E+15

USER DISTRIBUTION (CUMULATIVE) CUMMAT1 CUMPRP1

4 SPECIFIED CONTINUOUS

-8.00000E+00	0.10000				
-6.57000E+00	0.80000				
-4.77000E+00	0.10000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)	CUMMAT2	CUMPRP2		
4	SPECIFIED	CONTINUOUS			
-1.25000E+01	0.15000				
-9.00000E+00	0.45000				
-6.51000E+00	0.40000				
-5.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)	CUMMAT3	CUMPRP3		
4	SPECIFIED	CONTINUOUS			
-8.60000E+00	0.10000				
-8.00000E+00	0.60000				
-3.25000E+00	0.30000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(DATA)	DATAMAT1	DATAPRP1		
21	EQUAL	CONTINUOUS			
5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			
USER DISTRIBUTION	(DATA)	DATAMAT2	DATAPRP2		
9	EQUAL	CONTINUOUS			
2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01
7.94300E+01	8.90880E+01	1.03800E+02			
USER DISTRIBUTION	(DATA)	DATAMAT3	DATAPRP3		
12	EQUAL	CONTINUOUS			
1.22250E+00	9.30000E+00	1.09000E+01	1.38500E+01	2.74330E+01	3.46500E+01
4.61600E+01	5.01800E+01	6.15170E+01	7.38000E+01	8.78400E+01	9.49600E+01
USER DISTRIBUTION	(DELTA)	DELTMAT1	DELTPRP1		
14	SPECIFIED	DISCRETE			
5.08000E-02	0.07143				
1.01600E-01	0.07143				
1.52400E-01	0.07143				
1.93680E-01	0.07143				
2.19080E-01	0.07143				
2.28600E-01	0.07143				
2.50830E-01	0.07143				
2.79400E-01	0.07143				
3.04800E-01	0.07143				
3.49250E-01	0.07143				

3.81000E-01 0.07143
4.44500E-01 0.07143
5.58800E-01 0.07143
6.09600E-01 0.07141

USER DISTRIBUTION (DELTA) DELTMAT2 DELTPRP2
4 SPECIFIED DISCRETE
1.00000E+00 0.30000
2.00000E+00 0.15000
3.00000E+00 0.20000
4.00000E+00 0.35000

USER DISTRIBUTION (DELTA) DELTMAT3 DELTPRP3
6 SPECIFIED DISCRETE
-1.00000E+01 0.13000
2.00000E+00 0.13000
8.00000E+00 0.26000
2.30000E+01 0.15000
3.40000E+01 0.15000
4.00000E+01 0.18000

CORRELATION MATRIX

7
1 3 0.999
2 5 0.950
4 6 0.800
5 2 0.950
7 8 0.650
7 9 0.650
8 9 0.650

OUTPUT CORR HIST DATA

INPUT FILE FOR LHS TEST 7

TITLE CMS Test Input File for the LHS Code Test 7

NOBS 75
RANDOM SEED 933090934
NORMAL NORMMAT1 NORMPRP1
0.00000E+00 2.00000E-01
NORMAL NORMMAT2 NORMPRP2
5.77000E+02 1.04200E+03
NORMAL NORMMAT3 NORMPRP3
-3.67370E-02 8.32640E-02
LOGNORMAL LOGNMAT1 LOGNPRP1
1.00000E-02 2.13000E+00
LOGNORMAL LOGNMAT2 LOGNPRP2
1.00000E-03 3.50000E+02

LOGNORMAL		LOGNMAT3	LOGNPRP3		
1.00000E-04	5.25000E+04				
UNIFORM		UNIFMAT1	UNIFPRP1		
-5.00000E-01	5.00000E-01				
UNIFORM		UNIFMAT2	UNIFPRP2		
0.00000E+00	1.00000E+00				
UNIFORM		UNIFMAT3	UNIFPRP3		
1.25000E+01	5.00000E+02				
LOGUNIFORM		LOGUMAT1	LOGUPRP1		
1.00000E-17	1.00000E-11				
LOGUNIFORM		LOGUMAT2	LOGUPRP2		
1.00000E-06	1.00000E+03				
LOGUNIFORM		LOGUMAT3	LOGUPRP3		
5.60000E+13	5.60000E+15				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT1	CUMPRP1	
4	SPECIFIED		CONTINUOUS		
-8.00000E+00	0.10000				
-6.57000E+00	0.80000				
-4.77000E+00	0.10000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT2	CUMPRP2	
4	SPECIFIED		CONTINUOUS		
-1.25000E+01	0.15000				
-9.00000E+00	0.45000				
-6.51000E+00	0.40000				
-5.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT3	CUMPRP3	
4	SPECIFIED		CONTINUOUS		
-8.60000E+00	0.10000				
-8.00000E+00	0.60000				
-3.25000E+00	0.30000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(DATA)		DATAMAT1	DATAPRP1	
21	EQUAL		CONTINUOUS		
5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			
USER DISTRIBUTION	(DATA)		DATAMAT2	DATAPRP2	
9	EQUAL		CONTINUOUS		
2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01
7.94300E+01	8.90880E+01	1.03800E+02			

USER DISTRIBUTION (DATA)		DATAMAT3	DATAPRP3		
12	EQUAL	CONTINUOUS			
1.22250E+00	9.30000E+00	1.09000E+01	1.38500E+01	2.74330E+01	3.46500E+01
4.61600E+01	5.01800E+01	6.15170E+01	7.38000E+01	8.78400E+01	9.49600E+01
USER DISTRIBUTION (DELTA)		DELTMAT1	DELTPRP1		
14	SPECIFIED	DISCRETE			
5.08000E-02	0.07143				
1.01600E-01	0.07143				
1.52400E-01	0.07143				
1.93680E-01	0.07143				
2.19080E-01	0.07143				
2.28600E-01	0.07143				
2.50830E-01	0.07143				
2.79400E-01	0.07143				
3.04800E-01	0.07143				
3.49250E-01	0.07143				
3.81000E-01	0.07143				
4.44500E-01	0.07143				
5.58800E-01	0.07143				
6.09600E-01	0.07141				
USER DISTRIBUTION (DELTA)		DELTMAT2	DELTPRP2		
4	SPECIFIED	DISCRETE			
1.00000E+00	0.30000				
2.00000E+00	0.15000				
3.00000E+00	0.20000				
4.00000E+00	0.35000				
USER DISTRIBUTION (DELTA)		DELTMAT3	DELTPRP3		
6	SPECIFIED	DISCRETE			
-1.00000E+01	0.13000				
2.00000E+00	0.13000				
8.00000E+00	0.26000				
2.30000E+01	0.15000				
3.40000E+01	0.15000				
4.00000E+01	0.18000				
NORMAL		NORMMAT1	NORMPRP1		
0.00000E+00	2.00000E-01				
NORMAL		NORMMAT2	NORMPRP2		
5.77000E+02	1.04200E+03				
NORMAL		NORMMAT3	NORMPRP3		
-3.67370E-02	8.32640E-02				
LOGNORMAL		LOGNMAT1	LOGNPRP1		
1.00000E-02	2.13000E+00				

LOGNORMAL		LOGNMAT2	LOGNPRP2		
1.00000E-03	3.50000E+02				
LOGNORMAL		LOGNMAT3	LOGNPRP3		
1.00000E-04	5.25000E+04				
UNIFORM		UNIFMAT1	UNIFPRP1		
-5.00000E-01	5.00000E-01				
UNIFORM		UNIFMAT2	UNIFPRP2		
0.00000E+00	1.00000E+00				
UNIFORM		UNIFMAT3	UNIFPRP3		
1.25000E+01	5.00000E+02				
LOGUNIFORM		LOGUMAT1	LOGUPRP1		
1.00000E-17	1.00000E-11				
LOGUNIFORM		LOGUMAT2	LOGUPRP2		
1.00000E-06	1.00000E+03				
LOGUNIFORM		LOGUMAT3	LOGUPRP3		
5.60000E+13	5.60000E+15				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT1	CUMPRP1	
4	SPECIFIED		CONTINUOUS		
-8.00000E+00	0.10000				
-6.57000E+00	0.80000				
-4.77000E+00	0.10000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT2	CUMPRP2	
4	SPECIFIED		CONTINUOUS		
-1.25000E+01	0.15000				
-9.00000E+00	0.45000				
-6.51000E+00	0.40000				
-5.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT3	CUMPRP3	
4	SPECIFIED		CONTINUOUS		
-8.60000E+00	0.10000				
-8.00000E+00	0.60000				
-3.25000E+00	0.30000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(DATA)		DATAMAT1	DATAPRP1	
21	EQUAL		CONTINUOUS		
5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			
USER DISTRIBUTION	(DATA)		DATAMAT2	DATAPRP2	
9	EQUAL		CONTINUOUS		

2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01
7.94300E+01	8.90880E+01	1.03800E+02			
USER DISTRIBUTION (DATA)		DATAMAT3	DATAPRP3		
12	EQUAL	CONTINUOUS			
1.22250E+00	9.30000E+00	1.09000E+01	1.38500E+01	2.74330E+01	3.46500E+01
4.61600E+01	5.01800E+01	6.15170E+01	7.38000E+01	8.78400E+01	9.49600E+01
USER DISTRIBUTION (DELTA)		DELTMAT1	DELTPRP1		
14	SPECIFIED	DISCRETE			
5.08000E-02	0.07143				
1.01600E-01	0.07143				
1.52400E-01	0.07143				
1.93680E-01	0.07143				
2.19080E-01	0.07143				
2.28600E-01	0.07143				
2.50830E-01	0.07143				
2.79400E-01	0.07143				
3.04800E-01	0.07143				
3.49250E-01	0.07143				
3.81000E-01	0.07143				
4.44500E-01	0.07143				
5.58800E-01	0.07143				
6.09600E-01	0.07141				
USER DISTRIBUTION (DELTA)		DELTMAT2	DELTPRP2		
4	SPECIFIED	DISCRETE			
1.00000E+00	0.30000				
2.00000E+00	0.15000				
3.00000E+00	0.20000				
4.00000E+00	0.35000				
USER DISTRIBUTION (DELTA)		DELTMAT3	DELTPRP3		
6	SPECIFIED	DISCRETE			
-1.00000E+01	0.13000				
2.00000E+00	0.13000				
8.00000E+00	0.26000				
2.30000E+01	0.15000				
3.40000E+01	0.15000				
4.00000E+01	0.18000				
NORMAL		NORMMAT1	NORMPRP1		
0.00000E+00	2.00000E-01				
NORMAL		NORMMAT2	NORMPRP2		
5.77000E+02	1.04200E+03				
NORMAL		NORMMAT3	NORMPRP3		
-3.67370E-02	8.32640E-02				

LOGNORMAL		LOGNMAT1	LOGNPRP1		
1.00000E-02	2.13000E+00				
LOGNORMAL		LOGNMAT2	LOGNPRP2		
1.00000E-03	3.50000E+02				
LOGNORMAL		LOGNMAT3	LOGNPRP3		
1.00000E-04	5.25000E+04				
UNIFORM		UNIFMAT1	UNIFPRP1		
-5.00000E-01	5.00000E-01				
UNIFORM		UNIFMAT2	UNIFPRP2		
0.00000E+00	1.00000E+00				
UNIFORM		UNIFMAT3	UNIFPRP3		
1.25000E+01	5.00000E+02				
LOGUNIFORM		LOGUMAT1	LOGUPRP1		
1.00000E-17	1.00000E-11				
LOGUNIFORM		LOGUMAT2	LOGUPRP2		
1.00000E-06	1.00000E+03				
LOGUNIFORM		LOGUMAT3	LOGUPRP3		
5.60000E+13	5.60000E+15				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT1	CUMPRP1	
4	SPECIFIED		CONTINUOUS		
-8.00000E+00	0.10000				
-6.57000E+00	0.80000				
-4.77000E+00	0.10000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT2	CUMPRP2	
4	SPECIFIED		CONTINUOUS		
-1.25000E+01	0.15000				
-9.00000E+00	0.45000				
-6.51000E+00	0.40000				
-5.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT3	CUMPRP3	
4	SPECIFIED		CONTINUOUS		
-8.60000E+00	0.10000				
-8.00000E+00	0.60000				
-3.25000E+00	0.30000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(DATA)		DATAMAT1	DATAPRP1	
21	EQUAL		CONTINUOUS		
5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			

USER DISTRIBUTION (DATA)		DATAMAT2	DATAPRP2		
9	EQUAL	CONTINUOUS			
2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01
7.94300E+01	8.90880E+01	1.03800E+02			
USER DISTRIBUTION (DATA)		DATAMAT3	DATAPRP3		
12	EQUAL	CONTINUOUS			
1.22250E+00	9.30000E+00	1.09000E+01	1.38500E+01	2.74330E+01	3.46500E+01
4.61600E+01	5.01800E+01	6.15170E+01	7.38000E+01	8.78400E+01	9.49600E+01
USER DISTRIBUTION (DELTA)		DELTMAT1	DELTPRP1		
14	SPECIFIED	DISCRETE			
5.08000E-02	0.07143				
1.01600E-01	0.07143				
1.52400E-01	0.07143				
1.93680E-01	0.07143				
2.19080E-01	0.07143				
2.28600E-01	0.07143				
2.50830E-01	0.07143				
2.79400E-01	0.07143				
3.04800E-01	0.07143				
3.49250E-01	0.07143				
3.81000E-01	0.07143				
4.44500E-01	0.07143				
5.58800E-01	0.07143				
6.09600E-01	0.07141				
USER DISTRIBUTION (DELTA)		DELTMAT2	DELTPRP2		
4	SPECIFIED	DISCRETE			
1.00000E+00	0.30000				
2.00000E+00	0.15000				
3.00000E+00	0.20000				
4.00000E+00	0.35000				
USER DISTRIBUTION (DELTA)		DELTMAT3	DELTPRP3		
6	SPECIFIED	DISCRETE			
-1.00000E+01	0.13000				
2.00000E+00	0.13000				
8.00000E+00	0.26000				
2.30000E+01	0.15000				
3.40000E+01	0.15000				
4.00000E+01	0.18000				
NORMAL		NORMMAT1	NORMPRP1		
0.00000E+00	2.00000E-01				
NORMAL		NORMMAT2	NORMPRP2		
5.77000E+02	1.04200E+03				

NORMAL		NORMMAT3	NORMPRP3		
-3.67370E-02	8.32640E-02				
LOGNORMAL		LOGNMAT1	LOGNPRP1		
1.00000E-02	2.13000E+00				
LOGNORMAL		LOGNMAT2	LOGNPRP2		
1.00000E-03	3.50000E+02				
LOGNORMAL		LOGNMAT3	LOGNPRP3		
1.00000E-04	5.25000E+04				
UNIFORM		UNIFMAT1	UNIFPRP1		
-5.00000E-01	5.00000E-01				
UNIFORM		UNIFMAT2	UNIFPRP2		
0.00000E+00	1.00000E+00				
UNIFORM		UNIFMAT3	UNIFPRP3		
1.25000E+01	5.00000E+02				
LOGUNIFORM		LOGUMAT1	LOGUPRP1		
1.00000E-17	1.00000E-11				
LOGUNIFORM		LOGUMAT2	LOGUPRP2		
1.00000E-06	1.00000E+03				
LOGUNIFORM		LOGUMAT3	LOGUPRP3		
5.60000E+13	5.60000E+15				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT1	CUMPRP1	
4	SPECIFIED		CONTINUOUS		
-8.00000E+00	0.10000				
-6.57000E+00	0.80000				
-4.77000E+00	0.10000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT2	CUMPRP2	
4	SPECIFIED		CONTINUOUS		
-1.25000E+01	0.15000				
-9.00000E+00	0.45000				
-6.51000E+00	0.40000				
-5.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT3	CUMPRP3	
4	SPECIFIED		CONTINUOUS		
-8.60000E+00	0.10000				
-8.00000E+00	0.60000				
-3.25000E+00	0.30000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(DATA)		DATAMAT1	DATAPRP1	
21	EQUAL		CONTINUOUS		
5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01

1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			
USER DISTRIBUTION	(DATA)		DATAMAT2	DATAPRP2	
9	EQUAL		CONTINUOUS		
2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01
7.94300E+01	8.90880E+01	1.03800E+02			
USER DISTRIBUTION	(DATA)		DATAMAT3	DATAPRP3	
12	EQUAL		CONTINUOUS		
1.22250E+00	9.30000E+00	1.09000E+01	1.38500E+01	2.74330E+01	3.46500E+01
4.61600E+01	5.01800E+01	6.15170E+01	7.38000E+01	8.78400E+01	9.49600E+01
USER DISTRIBUTION	(DELTA)		DELTMAT1	DELTPRP1	
14	SPECIFIED		DISCRETE		
5.08000E-02	0.07143				
1.01600E-01	0.07143				
1.52400E-01	0.07143				
1.93680E-01	0.07143				
2.19080E-01	0.07143				
2.28600E-01	0.07143				
2.50830E-01	0.07143				
2.79400E-01	0.07143				
3.04800E-01	0.07143				
3.49250E-01	0.07143				
3.81000E-01	0.07143				
4.44500E-01	0.07143				
5.58800E-01	0.07143				
6.09600E-01	0.07141				
USER DISTRIBUTION	(DELTA)		DELTMAT2	DELTPRP2	
4	SPECIFIED		DISCRETE		
1.00000E+00	0.30000				
2.00000E+00	0.15000				
3.00000E+00	0.20000				
4.00000E+00	0.35000				
USER DISTRIBUTION	(DELTA)		DELTMAT3	DELTPRP3	
6	SPECIFIED		DISCRETE		
-1.00000E+01	0.13000				
2.00000E+00	0.13000				
8.00000E+00	0.26000				
2.30000E+01	0.15000				
3.40000E+01	0.15000				
4.00000E+01	0.18000				
NORMAL		NORMMAT1	NORMPRP1		
0.00000E+00	2.00000E-01				

NORMAL		NORMMAT2	NORMPRP2	
5.77000E+02	1.04200E+03			
NORMAL		NORMMAT3	NORMPRP3	
-3.67370E-02	8.32640E-02			
LOGNORMAL		LOGNMAT1	LOGNPRP1	
1.00000E-02	2.13000E+00			
LOGNORMAL		LOGNMAT2	LOGNPRP2	
1.00000E-03	3.50000E+02			
LOGNORMAL		LOGNMAT3	LOGNPRP3	
1.00000E-04	5.25000E+04			
UNIFORM		UNIFMAT1	UNIFPRP1	
-5.00000E-01	5.00000E-01			
UNIFORM		UNIFMAT2	UNIFPRP2	
0.00000E+00	1.00000E+00			
UNIFORM		UNIFMAT3	UNIFPRP3	
1.25000E+01	5.00000E+02			
LOGUNIFORM		LOGUMAT1	LOGUPRP1	
1.00000E-17	1.00000E-11			
LOGUNIFORM		LOGUMAT2	LOGUPRP2	
1.00000E-06	1.00000E+03			
LOGUNIFORM		LOGUMAT3	LOGUPRP3	
5.60000E+13	5.60000E+15			
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT1	CUMPRP1
4	SPECIFIED		CONTINUOUS	
-8.00000E+00	0.10000			
-6.57000E+00	0.80000			
-4.77000E+00	0.10000			
-2.00000E+00	0.00000			
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT2	CUMPRP2
4	SPECIFIED		CONTINUOUS	
-1.25000E+01	0.15000			
-9.00000E+00	0.45000			
-6.51000E+00	0.40000			
-5.00000E+00	0.00000			
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT3	CUMPRP3
4	SPECIFIED		CONTINUOUS	
-8.60000E+00	0.10000			
-8.00000E+00	0.60000			
-3.25000E+00	0.30000			
-2.00000E+00	0.00000			
USER DISTRIBUTION	(DATA)		DATAMAT1	DATAPRP1
21	EQUAL		CONTINUOUS	

5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			
USER DISTRIBUTION (DATA)		DATAMAT2 DATAPRP2			
9	EQUAL	CONTINUOUS			
2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01
7.94300E+01	8.90880E+01	1.03800E+02			
USER DISTRIBUTION (DATA)		DATAMAT3 DATAPRP3			
12	EQUAL	CONTINUOUS			
1.22250E+00	9.30000E+00	1.09000E+01	1.38500E+01	2.74330E+01	3.46500E+01
4.61600E+01	5.01800E+01	6.15170E+01	7.38000E+01	8.78400E+01	9.49600E+01
USER DISTRIBUTION (DELTA)		DELTMAT1 DELTPRP1			
14	SPECIFIED	DISCRETE			
5.08000E-02	0.07143				
1.01600E-01	0.07143				
1.52400E-01	0.07143				
1.93680E-01	0.07143				
2.19080E-01	0.07143				
2.28600E-01	0.07143				
2.50830E-01	0.07143				
2.79400E-01	0.07143				
3.04800E-01	0.07143				
3.49250E-01	0.07143				
3.81000E-01	0.07143				
4.44500E-01	0.07143				
5.58800E-01	0.07143				
6.09600E-01	0.07141				
USER DISTRIBUTION (DELTA)		DELTMAT2 DELTPRP2			
4	SPECIFIED	DISCRETE			
1.00000E+00	0.30000				
2.00000E+00	0.15000				
3.00000E+00	0.20000				
4.00000E+00	0.35000				
USER DISTRIBUTION (DELTA)		DELTMAT3 DELTPRP3			
6	SPECIFIED	DISCRETE			
-1.00000E+01	0.13000				
2.00000E+00	0.13000				
8.00000E+00	0.26000				
2.30000E+01	0.15000				
3.40000E+01	0.15000				
4.00000E+01	0.18000				

CORRELATION MATRIX

7
1 3 0.999
2 5 0.950
4 6 0.800
5 2 0.950
7 8 0.650
7 9 0.650
8 9 0.650

OUTPUT CORR HIST DATA

INPUT FILE FOR LHS TEST 8

TITLE CMS Test Input File for the LHS Code Test 8

NOBS 75
RANDOM SEED 933090934
NORMAL NORMMAT1 NORMPRP1
0.00000E+00 2.00000E-01
NORMAL NORMMAT2 NORMPRP2
5.77000E+02 1.04200E+03
NORMAL NORMMAT3 NORMPRP3
LOGNORMAL LOGNMAT1 LOGNPRP1
1.00000E-02 2.13000E+00
LOGNORMAL LOGNMAT2 LOGNPRP2
1.00000E-03 3.50000E+02
LOGNORMAL LOGNMAT3 LOGNPRP3
1.00000E-04 5.25000E+04
UNIFORM UNIFMAT1 UNIFPRP1
-5.00000E-01 5.00000E-01
UNIFORM UNIFMAT2 UNIFPRP2
0.00000E+00 1.00000E+00
UNIFORM UNIFMAT3 UNIFPRP3
1.25000E+01 5.00000E+02
LOGUNIFORM LOGUMAT1 LOGUPRP1
1.00000E-17 1.00000E-11
LOGUNIFORM LOGUMAT2 LOGUPRP2
1.00000E-06 1.00000E+03
LOGUNIFORM LOGUMAT3 LOGUPRP3
5.60000E+13 5.60000E+15
USER DISTRIBUTION (CUMULATIVE) CUMMAT1 CUMPRP1
4 SPECIFIED CONTINUOUS
-8.00000E+00 0.10000
-6.57000E+00 0.80000
-4.77000E+00 0.10000

-2.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT2	CUMPRP2	
4	SPECIFIED		CONTINUOUS		
-1.25000E+01	0.15000				
-9.00000E+00	0.45000				
-6.51000E+00	0.40000				
-5.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)		CUMMAT3	CUMPRP3	
4	SPECIFIED		CONTINUOUS		
-8.60000E+00	0.10000				
-8.00000E+00	0.60000				
-3.25000E+00	0.30000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(DATA)		DATAMAT1	DATAPRP1	
21	EQUAL		CONTINUOUS		
5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			
USER DISTRIBUTION	(DATA)		DATAMAT2	DATAPRP2	
9	EQUAL		CONTINUOUS		
2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01
7.94300E+01	8.90880E+01	1.03800E+02			
USER DISTRIBUTION	(DATA)		DATAMAT3	DATAPRP3	
12	EQUAL		CONTINUOUS		
1.22250E+00	9.30000E+00	1.09000E+01	1.38500E+01	2.74330E+01	3.46500E+01
4.61600E+01	5.01800E+01	6.15170E+01	7.38000E+01	8.78400E+01	9.49600E+01
USER DISTRIBUTION	(DELTA)		DELTMAT1	DELTPRP1	
14	SPECIFIED		DISCRETE		
5.08000E-02	0.07143				
1.01600E-01	0.07143				
1.52400E-01	0.07143				
1.93680E-01	0.07143				
2.19080E-01	0.07143				
2.28600E-01	0.07143				
2.50830E-01	0.07143				
2.79400E-01	0.07143				
3.04800E-01	0.07143				
3.49250E-01	0.07143				
3.81000E-01	0.07143				
4.44500E-01	0.07143				
5.58800E-01	0.07143				

6.09600E-01 0.07141
 USER DISTRIBUTION (DELTA) DELTMAT2 DELTPRP2
 4 SPECIFIED DISCRETE
 1.00000E+00 0.30000
 2.00000E+00 0.15000
 3.00000E+00 0.20000
 4.00000E+00 0.35000

USER DISTRIBUTION (DELTA) DELTMAT3 DELTPRP3
 6 SPECIFIED DISCRETE
 -1.00000E+01 0.13000
 2.00000E+00 0.13000
 8.00000E+00 0.26000
 2.30000E+01 0.15000
 3.40000E+01 0.15000
 4.00000E+01 0.18000

CORRELATION MATRIX

7
 1 3 0.999
 2 5 0.950
 4 6 0.800
 5 2 0.950
 7 8 0.650
 7 9 0.650
 8 9 0.650

OUTPUT CORR HIST DATA

INPUT FILE FOR LHS TEST 9

TITLE CMS Test Input File for the LHS Code Test 9

NOBS 75
 RANDOM SEED 933090934578
 NORMAL NORMMAT1 NORMPRP1
 0.00000E+00 2.00000E-01
 NORMAL NORMMAT2 NORMPRP2
 5.77000E+02 1.04200E+03
 NORMAL NORMMAT3 NORMPRP3
 -3.67370E-02 8.32640E-02
 LOGNORMAL LOGNMAT1 LOGNPRP1
 1.00000E-02 2.13000E+00
 LOGNORMAL LOGNMAT2 LOGNPRP2
 1.00000E-03 3.50000E+02
 LOGNORMAL LOGNMAT3 LOGNPRP3
 1.00000E-04 5.25000E+04
 UNIFORM UNIFMAT1 UNIFPRP1

-5.00000E-01	5.00000E-01				
UNIFORM	UNIFMAT2	UNIFPRP2			
0.00000E+00	1.00000E+00				
UNIFORM	UNIFMAT3	UNIFPRP3			
1.25000E+01	5.00000E+02				
LOGUNIFORM	LOGUMAT1	LOGUPRP1			
1.00000E-17	1.00000E-11				
LOGUNIFORM	LOGUMAT2	LOGUPRP2			
1.00000E-06	1.00000E+03				
LOGUNIFORM	LOGUMAT3	LOGUPRP3			
5.60000E+13	5.60000E+15				
USER DISTRIBUTION	(CUMULATIVE)	CUMMAT1	CUMPRP1		
4	SPECIFIED	CONTINUOUS			
-8.00000E+00	0.10000				
-6.57000E+00	0.80000				
-4.77000E+00	0.10000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)	CUMMAT2	CUMPRP2		
4	SPECIFIED	CONTINUOUS			
-1.25000E+01	0.15000				
-9.00000E+00	0.45000				
-6.51000E+00	0.40000				
-5.00000E+00	0.00000				
USER DISTRIBUTION	(CUMULATIVE)	CUMMAT3	CUMPRP3		
4	SPECIFIED	CONTINUOUS			
-8.60000E+00	0.10000				
-8.00000E+00	0.60000				
-3.25000E+00	0.30000				
-2.00000E+00	0.00000				
USER DISTRIBUTION	(DATA)	DATAMAT1	DATAPRP1		
21	EQUAL	CONTINUOUS			
5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			
USER DISTRIBUTION	(DATA)	DATAMAT2	DATAPRP2		
9	EQUAL	CONTINUOUS			
2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01
7.94300E+01	8.90880E+01	1.03800E+02			
USER DISTRIBUTION	(DATA)	DATAMAT3	DATAPRP3		
12	EQUAL	CONTINUOUS			
1.22250E+00	9.30000E+00	1.09000E+01	1.38500E+01	2.74330E+01	3.46500E+01

4.61600E+01 5.01800E+01 6.15170E+01 7.38000E+01 8.78400E+01 9.49600E+01

USER DISTRIBUTION (DELTA) DELTMAT1 DELTPRP1

14	SPECIFIED	DISCRETE
5.08000E-02	0.07143	
1.01600E-01	0.07143	
1.52400E-01	0.07143	
1.93680E-01	0.07143	
2.19080E-01	0.07143	
2.28600E-01	0.07143	
2.50830E-01	0.07143	
2.79400E-01	0.07143	
3.04800E-01	0.07143	
3.49250E-01	0.07143	
3.81000E-01	0.07143	
4.44500E-01	0.07143	
5.58800E-01	0.07143	
6.09600E-01	0.07141	

USER DISTRIBUTION (DELTA) DELTMAT2 DELTPRP2

4	SPECIFIED	DISCRETE
1.00000E+00	0.30000	
2.00000E+00	0.15000	
3.00000E+00	0.20000	
4.00000E+00	0.35000	

USER DISTRIBUTION (DELTA) DELTMAT3 DELTPRP3

6	SPECIFIED	DISCRETE
-1.00000E+01	0.13000	
2.00000E+00	0.13000	
8.00000E+00	0.26000	
2.30000E+01	0.15000	
3.40000E+01	0.15000	
4.00000E+01	0.18000	

CORRELATION MATRIX

7		
1	3	-0.999
2	5	-0.950
4	6	-0.800
5	2	-0.950
7	8	-0.650
7	9	-0.650
8	9	-0.650

OUTPUT CORR HIST DATA

INPUT FILE FOR LHS TEST 10

TITLE CMS Test Input File for the LHS Code Test 10

NOBS	75		
RANDOM SEED	933090934		
NORMAL		NORMMAT1	NORMPRP1
0.00000E+00	2.00000E-01		
NORMAL		NORMMAT2	NORMPRP2
5.77000E+02	1.04200E+03		
NORMAL		NORMMAT3	NORMPRP3
-3.67370E-02	8.32640E-02		
LOGNORMAL		LOGNMAT1	LOGNPRP1
1.00000E-02	2.13000E+00		
LOGNORMAL		LOGNMAT2	LOGNPRP2
1.00000E-03	3.50000E+02		
LOGNORMAL		LOGNMAT3	LOGNPRP3
1.00000E-04	5.25000E+04		
UNIFORM		UNIFMAT1	UNIFPRP1
-5.00000E-01	5.00000E-01		
UNIFORM		UNIFMAT2	UNIFPRP2
0.00000E+00	1.00000E+00		
UNIFORM		UNIFMAT3	UNIFPRP3
1.25000E+01	5.00000E+02		
LOGUNIFORM		LOGUMAT1	LOGUPRP1
1.00000E-17	1.00000E-11		
LOGUNIFORM		LOGUMAT2	LOGUPRP2
1.00000E-06	1.00000E+03		
LOGUNIFORM		LOGUMAT3	LOGUPRP3
5.60000E+13	5.60000E+15		
USER DISTRIBUTION	(CUMULATIVE)	CUMMAT1	CUMPRP1
4	SPECIFIED	CONTINUOUS	
-8.00000E+00	0.10000		
-6.57000E+00	0.80000		
-4.77000E+00	0.10000		
-2.00000E+00	0.00000		
USER DISTRIBUTION	(CUMULATIVE)	CUMMAT2	CUMPRP2
4	SPECIFIED	CONTINUOUS	
-1.25000E+01	0.15000		
-9.00000E+00	0.45000		
-6.51000E+00	0.40000		
-5.00000E+00	0.00000		
USER DISTRIBUTION	(CUMULATIVE)	CUMMAT3	CUMPRP3
4	SPECIFIED	CONTINUOUS	
-8.60000E+00	0.10000		

-8.00000E+00	0.60000				
-3.25000E+00	0.30000				
-2.00000E+00	0.00000				
USER DISTRIBUTION (DATA)		DATAMAT1	DATAPRP1		
21	EQUAL	CONTINUOUS			
5.80565E-02	9.55000E-02	1.03330E-01	1.07400E-01	1.15000E-01	1.20500E-01
1.22250E-01	1.23500E-01	1.29000E-01	1.38500E-01	1.44330E-01	1.46500E-01
1.61600E-01	1.61800E-01	1.65170E-01	1.78000E-01	1.78400E-01	1.79600E-01
2.02500E-01	2.07750E-01	2.52500E-01			
USER DISTRIBUTION (DATA)		DATAMAT2	DATAPRP2		
9	EQUAL	CONTINUOUS			
2.30500E+01	2.90600E+01	3.45620E+01	4.13200E+01	5.53900E+01	6.34200E+01
7.94300E+01	8.90880E+01	1.03800E+02			
USER DISTRIBUTION (DATA)		DATAMAT3	DATAPRP3		
12	EQUAL	CONTINUOUS			
1.22250E+00	9.30000E+00	1.09000E+01	1.38500E+01	2.74330E+01	3.46500E+01
4.61600E+01	5.01800E+01	6.15170E+01	7.38000E+01	8.78400E+01	9.49600E+01
USER DISTRIBUTION (DELTA)		DELTMAT1	DELTPRP1		
14	SPECIFIED	DISCRETE			
5.08000E-02	0.07143				
1.01600E-01	0.07143				
1.52400E-01	0.07143				
1.93680E-01	0.07143				
2.19080E-01	0.07143				
2.28600E-01	0.07143				
2.50830E-01	0.07143				
2.79400E-01	0.07143				
3.04800E-01	0.07143				
3.49250E-01	0.07143				
3.81000E-01	0.07143				
4.44500E-01	0.07143				
5.58800E-01	0.07143				
6.09600E-01	0.07141				
USER DISTRIBUTION (DELTA)		DELTMAT2	DELTPRP2		
4	SPECIFIED	DISCRETE			
1.00000E+00	0.30000				
2.00000E+00	0.15000				
3.00000E+00	0.20000				
4.00000E+00	0.35000				
USER DISTRIBUTION (DELTA)		DELTMAT3	DELTPRP3		
6	SPECIFIED	DISCRETE			
-1.00000E+01	0.13000				

2.00000E+00 0.13000
 8.00000E+00 0.26000
 2.30000E+01 0.15000
 3.40000E+01 0.15000
 4.00000E+01 0.18000

CORRELATION MATRIX

7
 1 3 0.999
 2 5 0.950
 4 6 0.800
 5 2 0.950
 7 8 0.650
 7 9 0.650
 8 9 0.650

OUTPUT CORR HITS DATA

OUTPUT FILE FOR LHS TEST 1

RANDOM SEED = 933090934

NUMBER OF VARIABLES = 21

NUMBER OF OBSERVATIONS = 75

AN INPUT CORRELATION MATRIX HAS BEEN SPECIFIED

THE SAMPLE INPUT VECTORS WILL BE PRINTED ALONG WITH THEIR CORRESPONDING RANKS

HISTOGRAMS OF THE ACTUAL SAMPLE WILL BE PLOTTED FOR EACH INPUT VARIABLE

THE CORRELATION MATRICES (RAW DATA AND RANK CORRELATIONS) WILL BE PRINTED

VARIABLE	DISTRIBUTION	RANGE	LABEL
1	NORMAL	0.0000E+00 TO 0.2000	NORMMAT1 NORMPRP1
2	NORMAL	577.0 TO 1042.	NORMMAT2 NORMPRP2
3	NORMAL	-3.6737E-02 TO 8.3264E-02	NORMMAT3 NORMPRP3
4	LOGNORMAL	1.0000E-02 TO 2.130	LOGNMAT1 LOGNPRP1
5	LOGNORMAL	1.0000E-03 TO 350.0	LOGNMAT2 LOGNPRP2
6	LOGNORMAL	1.0000E-04 TO 5.2500E+04	LOGNMAT3 LOGNPRP3
7	UNIFORM	-0.5000 TO 0.5000	UNIFMAT1 UNIFPRP1
8	UNIFORM	0.0000E+00 TO 1.000	UNIFMAT2 UNIFPRP2
9	UNIFORM	12.50 TO 500.0	UNIFMAT3 UNIFPRP3
10	LOGUNIFORM	1.0000E-17 TO 1.0000E-11	LOGUMAT1 LOGUPRP1
11	LOGUNIFORM	1.0000E-06 TO 1000.	LOGUMAT2 LOGUPRP2
12	LOGUNIFORM	5.6000E+13 TO 5.6000E+15	LOGUMAT3 LOGUPRP3
13	USER SUPPLIED DISTRIBUTION		(CUMULATIVE) CUMMAT1
14	USER SUPPLIED DISTRIBUTION		(CUMULATIVE) CUMMAT2
15	USER SUPPLIED DISTRIBUTION		(CUMULATIVE) CUMMAT3
16	USER SUPPLIED DISTRIBUTION		(DATA) DATAMAT1 DAT
17	USER SUPPLIED DISTRIBUTION		(DATA) DATAMAT2 DAT
18	USER SUPPLIED DISTRIBUTION		(DATA) DATAMAT3 DAT

19	USER SUPPLIED DISTRIBUTION	(DELTA)	DELTMAT1	D
20	USER SUPPLIED DISTRIBUTION	(DELTA)	DELTMAT2	D
21	USER SUPPLIED DISTRIBUTION	(DELTA)	DELTMAT3	D

INPUT RANK CORRELATION MATRIX

1	1.0000								
2	0.0000	1.0000							
3	0.9990	0.0000	1.0000						
4	0.0000	0.0000	0.0000	1.0000					
5	0.0000	0.9500	0.0000	0.0000	1.0000				
6	0.0000	0.0000	0.0000	0.8000	0.0000	1.0000			
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000		
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6500	1.0000	
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6500	0.6500	1.0000
	1	2	3	4	5	6	7	8	9

VARIABLES

LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(1)	X(2)	X(3)	X(4)	X(5)	X(6)	X(7)
1	1.546E-01	7.814E+02	5.587E-02	1.390E-01	1.286E-01	3.042E+00	-9.939E-0
2	1.008E-01	7.908E+02	2.679E-02	2.382E-01	4.892E-01	3.504E+00	3.863E-0
3	1.157E-01	9.056E+02	3.308E-02	1.250E-01	1.853E+01	8.707E-02	-3.450E-0
4	8.294E-02	7.667E+02	1.062E-02	6.878E-01	4.196E-02	3.374E+02	-1.557E-0
5	8.873E-02	7.847E+02	1.480E-02	1.112E-01	2.590E-01	1.057E+02	-4.615E-0
6	1.283E-01	7.455E+02	4.096E-02	1.062E-01	5.157E-01	3.557E-01	2.662E-0
7	1.191E-01	7.361E+02	3.438E-02	2.668E-02	8.740E-02	4.761E-03	-5.500E-0
8	1.201E-01	7.604E+02	3.534E-02	1.191E-01	3.486E-01	1.465E-01	-2.172E-0
9	1.305E-01	9.646E+02	4.279E-02	1.953E-02	1.701E+01	5.156E-04	6.570E-0
10	1.439E-01	8.224E+02	4.878E-02	3.728E-02	4.041E-01	1.539E-03	3.796E-0
11	1.419E-01	6.056E+02	4.901E-02	8.737E-02	4.000E-03	4.733E-02	-4.083E-0
12	7.728E-02	8.496E+02	6.720E-03	2.585E-02	5.316E+00	1.419E-02	3.198E-0
13	1.796E-01	7.938E+02	6.895E-02	7.830E-02	4.408E-01	1.676E+00	4.362E-0
14	7.080E-02	8.654E+02	7.381E-03	1.657E-01	7.981E+00	2.653E-01	-3.165E-0
15	9.041E-03	7.430E+02	-3.176E-02	1.168E-01	1.030E-01	5.535E+00	3.944E-0
16	1.001E-01	8.848E+02	2.427E-02	6.072E-02	1.303E+00	1.747E-01	2.133E-0
17	1.611E-01	8.787E+02	6.012E-02	5.243E-02	7.333E+00	2.469E+00	1.117E-0
18	9.597E-02	7.648E+02	2.051E-02	1.364E-01	1.549E-01	2.762E+01	-1.102E-0
19	1.055E-01	5.853E+02	2.577E-02	1.568E-01	1.000E-03	6.347E+00	-1.559E-0
20	1.844E-01	9.998E+02	7.501E-02	8.939E-01	3.500E+02	4.051E+01	-3.952E-0
21	5.024E-02	6.346E+02	-7.449E-03	3.389E-02	1.934E-02	5.176E-01	3.543E-0
22	9.894E-02	7.756E+02	2.118E-02	4.646E-02	6.026E-02	2.941E-03	2.383E-0
23	1.093E-01	8.304E+02	2.837E-02	1.145E+00	5.773E-01	1.175E+04	3.285E-0
24	1.474E-01	8.392E+02	5.291E-02	2.055E-01	1.427E+00	1.124E+00	-2.349E-0
25	1.041E-01	8.830E+02	2.482E-02	6.689E-02	2.271E+00	6.366E-02	1.811E-0

26	1.154E-01	7.080E+02	3.215E-02	1.535E-01	2.866E-02	2.421E-01	4.953E-0
27	8.641E-02	8.195E+02	1.651E-02	9.178E-02	7.731E-01	8.677E-01	-2.550E-0
28	2.398E-02	8.252E+02	-2.378E-02	2.565E-01	1.950E+00	1.209E-01	-3.291E-0
29	1.076E-01	8.627E+02	2.723E-02	2.933E-02	1.170E+01	3.863E+00	-3.117E-0
30	9.421E-02	8.154E+02	1.983E-02	3.339E-01	1.192E-01	1.503E+02	1.257E-0
31	-2.235E-08	7.721E+02	-3.674E-02	1.288E-01	2.333E-01	7.594E-01	4.576E-0
32	4.387E-02	7.776E+02	-9.647E-03	9.959E-01	8.364E-02	4.658E+03	1.448E-0
33	8.915E-02	9.309E+02	1.730E-02	1.021E-01	3.349E+01	7.931E+00	-7.949E-0
34	6.021E-02	9.024E+02	-6.423E-04	8.412E-02	5.203E+00	1.238E+01	-3.625E-0
35	3.629E-02	8.695E+02	-1.195E-02	2.009E-01	2.459E+00	2.212E+00	8.825E-0
36	3.104E-02	6.750E+02	-1.740E-02	1.720E-02	1.188E-02	1.038E-02	-1.755E-0
37	4.249E-02	8.345E+02	-1.326E-02	9.341E-02	8.935E-01	8.056E+00	2.864E-0
38	2.834E-02	8.066E+02	-1.865E-02	4.260E-02	3.735E-01	6.069E-03	-4.790E-0
39	2.000E-01	7.523E+02	8.326E-02	5.589E-02	1.764E-01	1.485E+00	-4.317E-0
40	1.351E-01	6.850E+02	4.433E-02	1.000E-02	4.898E-02	3.211E-02	-4.278E-0
41	6.824E-02	9.757E+02	1.586E-03	4.446E-02	4.954E+01	2.084E-01	1.709E-0
42	1.371E-01	7.162E+02	4.596E-02	1.821E-01	2.744E-01	2.091E+00	-1.203E-0
43	1.287E-01	8.089E+02	3.832E-02	3.277E-01	2.087E-01	1.799E+02	5.480E-0
44	5.503E-02	7.992E+02	-1.370E-03	2.905E-01	6.784E-01	3.707E-01	1.375E-0
45	6.337E-02	7.315E+02	1.472E-03	2.197E-01	6.922E-01	1.480E-02	2.272E-0
46	1.118E-01	8.382E+02	3.145E-02	3.525E-01	1.590E+00	1.575E+01	-4.935E-0
47	7.213E-02	7.130E+02	5.339E-03	7.458E-02	2.807E-02	1.029E-03	-2.891E-0
48	1.593E-01	8.024E+02	5.773E-02	6.304E-02	1.338E-01	1.942E-02	-2.043E-0
49	1.245E-01	6.250E+02	3.795E-02	4.294E-01	2.019E-03	1.130E+02	8.149E-0
50	5.349E-02	7.223E+02	-4.801E-03	1.487E-01	3.666E-02	4.492E-01	-4.536E-0
51	1.029E-01	7.299E+02	2.337E-02	1.895E+00	7.515E-02	5.250E+04	-2.655E-0
52	7.995E-02	6.874E+02	1.271E-02	6.994E-02	2.013E-02	1.227E+00	1.990E-0
53	9.713E-02	1.019E+03	2.217E-02	7.187E-02	1.134E+02	9.461E-01	2.953E-0
54	1.267E-01	8.115E+02	4.016E-02	1.703E-01	1.912E+00	5.694E-01	4.842E-0
55	9.081E-02	9.263E+02	1.830E-02	3.688E-01	1.383E+01	2.217E+01	3.437E-0
56	6.703E-02	6.973E+02	4.962E-03	1.748E-01	5.680E-02	1.809E+01	-1.426E-0
57	1.324E-01	9.445E+02	4.188E-02	7.538E-01	3.702E+01	7.030E+01	1.871E-0
58	5.828E-02	9.125E+02	-2.770E-03	6.577E-01	3.872E+00	1.027E+03	-4.390E-0
59	1.103E-01	7.953E+02	2.962E-02	4.846E-01	9.333E-01	1.300E+01	4.101E-0
60	7.518E-02	8.924E+02	9.935E-03	9.944E-02	6.045E+00	3.627E+01	4.311E-0
61	7.916E-02	8.439E+02	1.213E-02	5.538E-01	1.544E+00	2.695E+02	1.630E-0
62	9.209E-02	8.738E+02	1.857E-02	3.131E-01	1.074E+00	7.355E+01	4.694E-0
63	1.717E-01	8.967E+02	6.589E-02	4.494E-01	3.417E+00	6.270E+02	-4.655E-0
64	1.530E-01	6.560E+02	5.535E-02	2.724E-01	8.289E-03	5.145E+01	2.542E-0
65	4.705E-02	9.394E+02	-6.991E-03	2.230E-01	4.391E+00	5.073E+00	-3.696E-0
66	1.668E-01	8.573E+02	6.336E-02	2.817E-01	3.038E+00	4.016E+02	-2.004E-0
67	1.490E-01	7.574E+02	5.170E-02	1.943E-01	1.841E-01	5.264E-02	-1.918E-0

68	7.340E-02	7.512E+02	8.893E-03	1.744E+00	3.068E-01	2.492E+03	3.002E-0
69	8.526E-02	1.042E+03	1.557E-02	1.433E-02	1.577E+02	1.000E-04	2.383E-0
70	1.126E-01	9.194E+02	3.065E-02	2.465E-01	2.385E+01	1.660E+03	-3.909E-0
71	6.463E-02	8.554E+02	3.472E-03	4.937E-01	2.830E+00	1.022E+01	-6.939E-0
72	8.353E-02	8.461E+02	1.356E-02	3.997E-01	1.152E+00	7.326E+02	-2.740E-0
73	1.397E-01	6.636E+02	4.693E-02	5.024E-02	7.021E-03	2.935E-02	3.504E-0
74	1.174E-01	9.570E+02	3.400E-02	3.850E-02	9.696E+00	9.654E-02	-2.252E-0
75	1.228E-01	7.042E+02	3.702E-02	5.807E-01	1.307E-02	2.923E+01	-1.302E-0

LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(11)	X(12)	X(13)	X(14)	X(15)	X(16)	X(17)
1	7.931E-06	1.740E+14	-5.323E+00	-5.598E+00	-7.694E+00	2.029E-01	9.254E+0
2	1.162E-05	2.606E+14	-6.077E+00	-6.342E+00	-4.229E+00	1.390E-01	2.639E+0
3	2.020E-01	8.655E+14	-6.272E+00	-8.964E+00	-6.927E+00	5.809E-02	9.880E+0
4	5.276E+01	1.147E+14	-4.858E+00	-7.018E+00	-5.523E+00	1.184E-01	3.721E+0
5	8.870E-04	1.618E+14	-6.544E+00	-7.284E+00	-2.801E+00	9.187E-02	4.016E+0
6	9.155E-01	1.266E+15	-5.448E+00	-6.650E+00	-2.386E+00	1.546E-01	3.788E+0
7	1.167E+00	7.919E+13	-6.325E+00	-5.726E+00	-3.235E+00	1.617E-01	9.387E+0
8	8.915E-02	4.253E+15	-5.680E+00	-5.539E+00	-4.360E+00	1.265E-01	2.935E+0
9	4.286E-05	6.288E+13	-2.816E+00	-7.866E+00	-4.954E+00	1.790E-01	9.540E+0
10	3.566E-06	7.147E+14	-5.855E+00	-6.146E+00	-2.228E+00	1.042E-01	7.958E+0
11	1.046E+02	3.135E+15	-5.930E+00	-5.096E+00	-2.658E+00	1.527E-01	7.727E+0
12	3.711E-02	3.900E+14	-6.433E+00	-5.502E+00	-3.435E+00	1.616E-01	4.345E+0
13	1.824E-06	1.205E+14	-4.924E+00	-8.077E+00	-3.955E+00	1.087E-01	3.136E+0
14	2.884E-06	2.402E+15	-5.174E+00	-8.495E+00	-8.596E+00	1.453E-01	3.038E+0
15	1.509E+02	1.618E+15	-3.614E+00	-5.048E+00	-3.864E+00	1.063E-01	3.188E+0
16	5.276E-04	2.576E+14	-5.040E+00	-5.416E+00	-2.138E+00	1.165E-01	4.919E+0
17	2.215E+01	5.745E+14	-4.782E+00	-6.160E+00	-8.515E+00	2.499E-01	3.491E+0
18	6.188E-06	1.313E+14	-5.554E+00	-7.962E+00	-7.874E+00	1.630E-01	3.437E+0
19	4.446E-01	6.348E+13	-6.465E+00	-1.044E+01	-6.234E+00	1.451E-01	6.324E+0
20	2.177E-05	2.886E+14	-6.375E+00	-6.057E+00	-5.655E+00	8.774E-02	2.338E+0
21	4.528E-06	8.433E+13	-7.205E+00	-7.603E+00	-2.730E+00	1.894E-01	3.293E+0
22	3.669E+00	1.790E+15	-6.146E+00	-9.911E+00	-5.386E+00	1.716E-01	7.481E+0
23	9.180E-03	2.847E+15	-5.608E+00	-9.540E+00	-2.300E+00	1.211E-01	3.920E+0
24	1.214E-04	1.436E+15	-3.356E+00	-9.305E+00	-2.536E+00	1.461E-01	1.014E+0
25	3.844E+01	5.852E+14	-7.014E+00	-7.034E+00	-5.905E+00	1.787E-01	3.890E+0
26	2.949E-04	4.683E+14	-4.904E+00	-8.935E+00	-6.054E+00	1.231E-01	5.800E+0
27	2.034E+02	7.099E+13	-5.007E+00	-8.805E+00	-2.852E+00	1.288E-01	7.179E+0
28	3.459E+02	1.505E+14	-4.962E+00	-5.303E+00	-4.791E+00	1.435E-01	5.999E+0
29	1.260E-02	4.891E+14	-2.437E+00	-6.685E+00	-3.170E+00	1.149E-01	4.242E+0
30	2.382E+00	4.751E+15	-6.111E+00	-7.784E+00	-2.962E+00	1.784E-01	3.644E+0
31	3.535E-01	5.139E+14	-5.262E+00	-7.622E+00	-6.037E+00	1.230E-01	8.278E+0
32	1.789E-01	4.172E+14	-5.898E+00	-8.326E+00	-5.506E+00	1.781E-01	5.685E+0

33	4.521E+02	1.006E+14	-5.477E+00	-5.231E+00	-3.361E+00	1.331E-01	6.183E+0
34	1.642E-06	9.649E+14	-4.840E+00	-8.163E+00	-6.391E+00	1.783E-01	6.929E+0
35	6.130E-02	1.283E+15	-7.555E+00	-5.638E+00	-7.416E+00	1.226E-01	4.677E+0
36	1.450E-04	1.976E+15	-6.357E+00	-7.368E+00	-7.793E+00	1.782E-01	5.607E+0
37	7.340E+02	8.058E+14	-4.122E+00	-8.664E+00	-2.675E+00	1.491E-01	6.143E+0
38	1.114E-01	3.532E+15	-5.715E+00	-1.005E+01	-4.735E+00	1.791E-01	8.897E+0
39	7.733E+02	8.949E+14	-5.875E+00	-7.507E+00	-2.604E+00	2.183E-01	2.446E+0
40	2.162E+00	3.960E+15	-5.069E+00	-7.398E+00	-8.154E+00	1.195E-01	5.421E+0
41	6.482E-05	3.253E+14	-7.719E+00	-5.184E+00	-7.490E+00	1.409E-01	8.699E+0
42	1.147E+01	2.128E+14	-6.234E+00	-1.185E+01	-5.187E+00	1.804E-01	6.034E+0
43	1.390E-03	1.469E+15	-4.988E+00	-5.253E+00	-4.115E+00	1.386E-01	7.844E+0
44	2.300E-03	2.175E+15	-6.514E+00	-7.166E+00	-4.619E+00	1.654E-01	3.086E+0
45	3.214E-03	1.118E+15	-5.286E+00	-8.632E+00	-2.068E+00	1.360E-01	5.172E+0
46	7.334E+00	3.742E+14	-6.059E+00	-7.237E+00	-4.306E+00	2.076E-01	9.112E+0
47	1.936E-04	9.169E+13	-6.471E+00	-5.850E+00	-3.804E+00	1.052E-01	3.393E+0
48	7.717E-02	2.324E+15	-5.576E+00	-6.931E+00	-6.622E+00	1.211E-01	2.751E+0
49	1.754E-03	1.138E+15	-5.757E+00	-6.269E+00	-4.495E+00	1.962E-01	6.658E+0
50	1.021E-04	1.874E+14	-4.814E+00	-5.914E+00	-8.025E+00	1.038E-01	2.608E+0
51	3.285E-01	5.950E+13	-5.788E+00	-6.066E+00	-8.288E+00	1.108E-01	4.061E+0
52	2.149E-02	4.403E+14	-6.170E+00	-1.135E+01	-3.156E+00	1.253E-01	2.831E+0
53	4.726E+00	6.430E+14	-5.983E+00	-1.226E+01	-3.003E+00	1.628E-01	2.983E+0
54	4.179E-03	1.327E+14	-7.931E+00	-6.829E+00	-7.041E+00	1.617E-01	4.426E+0
55	2.857E+02	9.049E+13	-5.145E+00	-5.787E+00	-5.032E+00	1.618E-01	5.578E+0
56	1.272E-06	1.886E+15	-5.204E+00	-6.525E+00	-2.405E+00	9.943E-02	8.351E+0
57	2.964E-02	1.052E+15	-5.819E+00	-8.229E+00	-3.707E+00	2.037E-01	3.551E+0
58	1.304E-05	1.471E+14	-5.384E+00	-8.768E+00	-2.461E+00	2.061E-01	2.421E+0
59	1.887E-05	2.438E+14	-5.532E+00	-6.439E+00	-8.201E+00	1.767E-01	8.841E+0
60	6.706E+01	4.434E+15	-6.295E+00	-8.414E+00	-8.430E+00	1.021E-01	9.971E+0
61	4.249E-04	3.681E+15	-5.999E+00	-8.516E+00	-2.010E+00	1.219E-01	8.488E+0
62	2.774E-05	3.412E+15	-5.633E+00	-5.693E+00	-8.093E+00	1.612E-01	8.161E+0
63	5.867E+00	2.940E+15	-6.216E+00	-5.965E+00	-6.487E+00	7.594E-02	4.827E+0
64	3.264E+01	3.033E+14	-5.415E+00	-6.464E+00	-3.545E+00	1.158E-01	1.034E+0
65	5.601E-05	2.212E+14	-6.016E+00	-5.402E+00	-2.211E+00	2.312E-01	6.872E+0
66	7.792E-03	3.531E+14	-7.362E+00	-5.116E+00	-3.094E+00	1.672E-01	8.631E+0
67	1.636E+00	1.660E+15	-4.284E+00	-7.703E+00	-7.309E+00	1.830E-01	8.113E+0
68	6.515E-04	6.657E+14	-2.311E+00	-5.870E+00	-7.181E+00	2.059E-01	5.039E+0
69	1.986E+01	7.220E+13	-5.098E+00	-1.105E+01	-6.295E+00	1.121E-01	3.297E+0
70	5.516E-03	1.933E+14	-6.569E+00	-1.068E+01	-2.895E+00	1.312E-01	9.691E+0
71	1.183E+02	7.764E+14	-6.760E+00	-8.041E+00	-6.732E+00	1.439E-01	7.268E+0
72	6.520E-01	5.433E+15	-5.344E+00	-6.244E+00	-5.252E+00	1.235E-01	5.921E+0
73	1.991E-02	2.674E+15	-5.699E+00	-6.386E+00	-6.887E+00	1.645E-01	2.775E+0
74	1.131E-03	5.099E+15	-5.422E+00	-6.773E+00	-5.748E+00	1.221E-01	2.514E+0

75 1.210E+01 1.072E+14 -5.228E+00 -1.188E+01 -7.573E+00 9.805E-02 6.484E+0

LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(21)
1	4.000E+01
2	3.400E+01
3	4.000E+01
4	4.000E+01
5	8.000E+00
6	4.000E+01
7	-1.000E+01
8	2.300E+01
9	-1.000E+01
10	4.000E+01
11	3.400E+01
12	2.300E+01
13	2.000E+00
14	2.000E+00
15	2.300E+01
16	8.000E+00
17	4.000E+01
18	8.000E+00
19	8.000E+00
20	2.000E+00
21	8.000E+00
22	2.300E+01
23	8.000E+00
24	4.000E+01
25	8.000E+00
26	4.000E+01
27	2.300E+01
28	2.300E+01
29	-1.000E+01
30	3.400E+01
31	3.400E+01
32	8.000E+00
33	-1.000E+01
34	3.400E+01
35	4.000E+01
36	2.300E+01
37	3.400E+01
38	8.000E+00
39	8.000E+00

40 2.300E+01
 41 2.000E+00
 42 4.000E+01
 43 8.000E+00
 44 2.300E+01
 45 -1.000E+01
 46 8.000E+00
 47 8.000E+00
 48 2.000E+00
 49 2.000E+00
 50 4.000E+01
 51 8.000E+00
 52 -1.000E+01
 53 3.400E+01
 54 4.000E+01
 55 8.000E+00
 56 3.400E+01
 57 2.000E+00
 58 4.000E+01
 59 2.000E+00
 60 8.000E+00
 61 -1.000E+01
 62 8.000E+00
 63 3.400E+01
 64 2.300E+01
 65 4.000E+01
 66 3.400E+01
 67 8.000E+00
 68 8.000E+00
 69 2.300E+01
 70 8.000E+00
 71 2.000E+00
 72 -1.000E+01
 73 -1.000E+01
 74 3.400E+01
 75 2.000E+00

RANKS OF LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(1)	X(2)	X(3)	X(4)	X(5)	X(6)	X(7)
1	68.	30.	68.	37.	22.	40.	31
2	39.	32.	42.	50.	36.	41.	67
3	49.	63.	49.	34.	68.	17.	12
4	26.	26.	24.	69.	13.	66.	37

5	30.	31.	28.	31.	29.	61.	3
6	56.	20.	57.	30.	37.	25.	58
7	51.	18.	51.	6.	19.	6.	34
8	52.	24.	52.	33.	32.	20.	22
9	58.	71.	59.	4.	67.	2.	43
10	64.	42.	63.	9.	34.	4.	66
11	63.	2.	64.	25.	3.	14.	7
12	23.	50.	20.	5.	60.	9.	62
13	73.	33.	73.	23.	35.	36.	71
14	19.	54.	21.	41.	63.	24.	14
15	2.	19.	2.	32.	20.	44.	68
16	38.	59.	39.	17.	46.	21.	54
17	70.	57.	70.	15.	62.	39.	46
18	35.	25.	35.	36.	24.	54.	30
19	42.	1.	41.	40.	1.	45.	26
20	74.	73.	74.	71.	75.	57.	8
21	10.	4.	9.	8.	8.	28.	65
22	37.	28.	36.	13.	16.	5.	40
23	44.	44.	44.	73.	38.	74.	63
24	65.	47.	66.	47.	47.	33.	20
25	41.	58.	40.	19.	52.	16.	52
26	48.	12.	48.	39.	11.	23.	75
27	29.	41.	30.	26.	41.	31.	19
28	3.	43.	3.	52.	51.	19.	13
29	43.	53.	43.	7.	65.	42.	15
30	34.	40.	34.	58.	21.	63.	47
31	1.	27.	1.	35.	28.	30.	72
32	8.	29.	8.	72.	18.	73.	49
33	31.	67.	31.	29.	70.	46.	32
34	14.	62.	14.	24.	59.	49.	11
35	6.	55.	7.	46.	53.	38.	45
36	5.	7.	5.	3.	6.	8.	25
37	7.	45.	6.	27.	42.	47.	59
38	4.	37.	4.	11.	33.	7.	2
39	75.	22.	75.	16.	25.	35.	38
40	60.	8.	60.	1.	14.	13.	6
41	18.	72.	16.	12.	72.	22.	51
42	61.	14.	61.	44.	30.	37.	29
43	57.	38.	55.	57.	27.	64.	42
44	12.	35.	13.	55.	39.	26.	48
45	15.	17.	15.	48.	40.	10.	55
46	46.	46.	47.	59.	49.	51.	1

47	20.	13.	19.	22.	10.	3.	16
48	69.	36.	69.	18.	23.	11.	23
49	54.	3.	54.	62.	2.	62.	44
50	11.	15.	11.	38.	12.	27.	4
51	40.	16.	38.	75.	17.	75.	18
52	25.	9.	26.	20.	9.	34.	53
53	36.	74.	37.	21.	73.	32.	60
54	55.	39.	56.	42.	50.	29.	74
55	32.	66.	32.	60.	66.	53.	64
56	17.	10.	18.	43.	15.	52.	27
57	59.	69.	58.	70.	71.	59.	39
58	13.	64.	12.	68.	57.	70.	5
59	45.	34.	45.	64.	43.	50.	69
60	22.	60.	23.	28.	61.	56.	70
61	24.	48.	25.	66.	48.	65.	50
62	33.	56.	33.	56.	44.	60.	73
63	72.	61.	72.	63.	56.	68.	35
64	67.	5.	67.	53.	5.	58.	57
65	9.	68.	10.	49.	58.	43.	10
66	71.	52.	71.	54.	55.	67.	36
67	66.	23.	65.	45.	26.	15.	24
68	21.	21.	22.	74.	31.	72.	61
69	28.	75.	29.	2.	74.	1.	56
70	47.	65.	46.	51.	69.	71.	9
71	16.	51.	17.	65.	54.	48.	33
72	27.	49.	27.	61.	45.	69.	17
73	62.	6.	62.	14.	4.	12.	41
74	50.	70.	50.	10.	64.	18.	21
75	53.	11.	53.	67.	7.	55.	28

RANKS OF LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(11)	X(12)	X(13)	X(14)	X(15)	X(16)	X(17)
1	8.	19.	50.	64.	11.	68.	68
2	9.	26.	24.	49.	44.	35.	6
3	45.	45.	18.	12.	18.	1.	72
4	65.	12.	65.	39.	31.	18.	23
5	25.	18.	9.	35.	61.	4.	27
6	50.	51.	45.	44.	69.	44.	24
7	51.	6.	16.	61.	53.	47.	69
8	42.	71.	38.	65.	42.	29.	10
9	14.	2.	73.	27.	37.	62.	70
10	5.	42.	32.	53.	71.	9.	57
11	67.	66.	29.	74.	64.	43.	55

12	39.	32.	13.	66.	51.	46.	30
13	3.	13.	63.	24.	46.	12.	14
14	4.	62.	55.	19.	1.	40.	12
15	69.	55.	71.	75.	47.	11.	15
16	23.	25.	59.	67.	73.	17.	34
17	62.	38.	68.	52.	2.	75.	20
18	7.	14.	42.	26.	9.	51.	19
19	48.	3.	12.	7.	25.	39.	47
20	12.	27.	14.	55.	30.	3.	1
21	6.	7.	5.	31.	62.	66.	16
22	55.	57.	22.	9.	33.	55.	54
23	34.	64.	40.	10.	70.	21.	26
24	18.	53.	72.	11.	66.	41.	74
25	64.	39.	6.	38.	28.	61.	25
26	21.	35.	64.	13.	26.	26.	41
27	70.	4.	60.	14.	60.	30.	52
28	72.	17.	62.	69.	38.	37.	43
29	35.	36.	74.	43.	54.	15.	29
30	54.	73.	23.	28.	58.	60.	22
31	47.	37.	52.	30.	27.	25.	60
32	44.	33.	30.	21.	32.	57.	40
33	73.	10.	44.	71.	52.	32.	46
34	2.	47.	66.	23.	23.	59.	51
35	40.	52.	3.	63.	14.	24.	32
36	19.	59.	15.	34.	10.	58.	39
37	74.	44.	70.	16.	63.	42.	45
38	43.	68.	36.	8.	39.	63.	66
39	75.	46.	31.	32.	65.	73.	3
40	53.	70.	58.	33.	6.	19.	37
41	16.	29.	2.	72.	13.	36.	64
42	59.	22.	19.	3.	35.	64.	44
43	27.	54.	61.	70.	45.	34.	56
44	29.	60.	10.	37.	40.	53.	13
45	30.	49.	51.	17.	74.	33.	36
46	58.	31.	25.	36.	43.	72.	67
47	20.	9.	11.	59.	48.	10.	18
48	41.	61.	41.	40.	21.	20.	7
49	28.	50.	35.	50.	41.	67.	49
50	17.	20.	67.	57.	8.	8.	5
51	46.	1.	34.	54.	4.	13.	28
52	37.	34.	21.	4.	55.	28.	9
53	56.	40.	28.	1.	57.	50.	11

54	31.	15.	1.	41.	17.	48.	31
55	71.	8.	56.	60.	36.	49.	38
56	1.	58.	54.	45.	68.	6.	61
57	38.	48.	33.	22.	49.	69.	21
58	10.	16.	48.	15.	67.	71.	2
59	11.	24.	43.	47.	5.	56.	65
60	66.	72.	17.	20.	3.	7.	73
61	22.	69.	27.	18.	75.	22.	62
62	13.	67.	39.	62.	7.	45.	59
63	57.	65.	20.	56.	22.	2.	33
64	63.	28.	47.	46.	50.	16.	75
65	15.	23.	26.	68.	72.	74.	50
66	33.	30.	4.	73.	56.	54.	63
67	52.	56.	69.	29.	15.	65.	58
68	24.	41.	75.	58.	16.	70.	35
69	61.	5.	57.	5.	24.	14.	17
70	32.	21.	8.	6.	59.	31.	71
71	68.	43.	7.	25.	20.	38.	53
72	49.	75.	49.	51.	34.	27.	42
73	36.	63.	37.	48.	19.	52.	8
74	26.	74.	46.	42.	29.	23.	4
75	60.	11.	53.	2.	12.	5.	48

RANKS OF LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(21)
1	69.
2	56.
3	69.
4	69.
5	30.
6	69.
7	5.
8	45.
9	5.
10	69.
11	56.
12	45.
13	15.
14	15.
15	45.
16	30.
17	69.
18	30.

19	30.
20	15.
21	30.
22	45.
23	30.
24	69.
25	30.
26	69.
27	45.
28	45.
29	5.
30	56.
31	56.
32	30.
33	5.
34	56.
35	69.
36	45.
37	56.
38	30.
39	30.
40	45.
41	15.
42	69.
43	30.
44	45.
45	5.
46	30.
47	30.
48	15.
49	15.
50	69.
51	30.
52	5.
53	56.
54	69.
55	30.
56	56.
57	15.
58	69.
59	15.
60	30.

61	5.
62	30.
63	56.
64	45.
65	69.
66	56.
67	30.
68	30.
69	45.
70	30.
71	15.
72	5.
73	5.
74	56.
75	15.

HISTOGRAM FOR VARIABLE NO. 1 NORMAL DISTRIBUTION

MIDPOINT	FREQ.	
-0.5000000E-02	1	X
0.5000000E-02	1	X
0.1500000E-01	0	
0.2500000E-01	2	XX
0.3500000E-01	2	XX
0.4500000E-01	3	XXX
0.5500000E-01	4	XXXX
0.6500001E-01	5	XXXXX
0.7500000E-01	7	XXXXXXXX
0.8500000E-01	6	XXXXXX
0.9500000E-01	6	XXXXXX
0.1050000	7	XXXXXXXX
0.1150000	7	XXXXXXXX
0.1250000	6	XXXXXX
0.1350000	5	XXXXX
0.1450000	4	XXXX
0.1550000	3	XXX
0.1650000	2	XX
0.1750000	2	XX
0.1850000	1	X
0.1950000	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-0.2235174E-07	0.2000000	0.2000001	0.9982305E-01	0.1000560	0.17

HISTOGRAM FOR VARIABLE NO. 2 NORMAL DISTRIBUTION

MIDPOINT	FREQ.	
586.5001	1	X
609.5001	1	X
632.5001	2	XX
655.5001	2	XX
678.5001	3	XXX
701.5001	4	XXXX
724.5001	4	XXXX
747.5001	6	XXXXXX
770.5001	7	XXXXXXXX
793.5001	6	XXXXXX
816.5001	7	XXXXXXXX
839.5001	7	XXXXXXXX
862.5001	6	XXXXXX
885.5001	5	XXXXX
908.5001	4	XXXX
931.5001	3	XXX
954.5001	3	XXX
977.5001	1	X
1000.500	1	X
1023.500	1	X
1046.500	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
585.3286	1042.000	456.6714	809.8748	808.8511	966

HISTOGRAM FOR VARIABLE NO. 3 NORMAL DISTRIBUTION

MIDPOINT	FREQ.	
-0.3899998E-01	1	X
-0.3299998E-01	1	X
-0.2699999E-01	0	
-0.2099999E-01	2	XX
-0.1499999E-01	2	XX
-0.8999996E-02	4	XXXX
-0.2999999E-02	4	XXXX
0.2999999E-02	5	XXXXX
0.8999996E-02	5	XXXXX
0.1499999E-01	7	XXXXXXXX
0.2099999E-01	7	XXXXXXXX
0.2699999E-01	7	XXXXXXXX

0.3299998E-01	7	XXXXXXX
0.3899998E-01	6	XXXXXXX
0.4499998E-01	4	XXXX
0.5099998E-01	4	XXXX
0.5699997E-01	3	XXX
0.6299997E-01	3	XXX
0.6899997E-01	1	X
0.7499997E-01	1	X
0.8099996E-01	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-0.3673701E-01	0.8326402E-01	0.1200010	0.2322436E-01	0.2336514E-01	0.63

HISTOGRAM FOR VARIABLE NO. 4 LOGNORMAL DISTRIBUTION

MIDPOINT	FREQ.	
0.4699997E-01	27	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.1409999	17	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.2349999	10	XXXXXXXXXXXX
0.3289998	6	XXXXXXX
0.4229998	3	XXX
0.5169997	3	XXX
0.6109996	2	XX
0.7049996	1	X
0.7989995	1	X
0.8929994	1	X
0.9869993	1	X
1.080999	0	
1.174999	1	X
1.268999	0	
1.362999	0	
1.456999	0	
1.550999	0	
1.644999	0	
1.738999	1	X
1.832999	0	
1.926999	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.9999994E-02	1.894962	1.884962	0.2694961	0.1486647	0.12

HISTOGRAM FOR VARIABLE NO. 5 LOGNORMAL DISTRIBUTION

MIDPOINT	FREQ.
----------	-------

40300.00	0	
42900.00	0	
45500.00	0	
48100.00	0	
50700.00	0	
53300.00	1	X
	75	

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.9999979E-04	52500.10	52500.10	1033.231	2.212465	0.37

HISTOGRAM FOR VARIABLE NO. 7 UNIFORM DISTRIBUTION

MIDPOINT	FREQ.	
-0.5144998	1	X
-0.4654998	3	XXX
-0.4164998	4	XXXX
-0.3674998	4	XXXX
-0.3184998	3	XXX
-0.2694998	4	XXXX
-0.2204998	4	XXXX
-0.1714998	3	XXX
-0.1224999	5	XXXXX
-0.7349989E-01	3	XXX
-0.2449990E-01	4	XXXX
0.2450008E-01	3	XXX
0.7350007E-01	4	XXXX
0.1225001	4	XXXX
0.1715000	3	XXX
0.2205000	4	XXXX
0.2695000	3	XXX
0.3185000	4	XXXX
0.3675000	4	XXXX
0.4165000	4	XXXX
0.4655000	3	XXX
0.5145000	1	X
	75	

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-0.4935275	0.4952782	0.9888058	0.1103552E-03	-0.4317144E-02	0.83

HISTOGRAM FOR VARIABLE NO. 8 UNIFORM DISTRIBUTION

MIDPOINT	FREQ.	
0.2449999E-01	3	XXX
0.7349998E-01	4	XXXX

0.1225000	4	XXXX
0.1715000	4	XXXX
0.2204999	3	XXX
0.2694999	4	XXXX
0.3184999	4	XXXX
0.3674999	4	XXXX
0.4164999	4	XXXX
0.4654999	3	XXX
0.5144999	3	XXX
0.5634999	4	XXXX
0.6124998	3	XXX
0.6614998	4	XXXX
0.7104998	4	XXXX
0.7594997	4	XXXX
0.8084997	4	XXXX
0.8574997	3	XXX
0.9064996	4	XXXX
0.9554996	3	XXX
1.004500	2	XX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.3375098E-02	0.9870160	0.9836408	0.5003692	0.4948947	0.83

HISTOGRAM FOR VARIABLE NO. 9 UNIFORM DISTRIBUTION

MIDPOINT	FREQ.
12.00000	2 XX
36.00001	3 XXX
60.00002	4 XXXX
84.00002	4 XXXX
108.0000	4 XXXX
132.0000	4 XXXX
156.0000	3 XXX
180.0000	4 XXXX
204.0000	4 XXXX
228.0000	3 XXX
252.0000	4 XXXX
276.0000	3 XXX
300.0000	4 XXXX
324.0000	4 XXXX
348.0000	4 XXXX
372.0000	3 XXX
396.0000	4 XXXX

253.5000	0	
292.5000	1	X
331.5000	1	X
370.5000	0	
409.5000	0	
448.5000	1	X
487.5000	0	
526.4999	0	
565.4999	0	
604.4999	0	
643.4999	0	
682.4999	0	
721.4999	1	X
760.4999	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.1271550E-05	773.3129	773.3129	46.09647	0.2964271E-01	197

HISTOGRAM FOR VARIABLE NO. 12 LOGUNIFORM DISTRIBUTION

MIDPOINT	FREQ.	
0.1350000E+15	26	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.4050000E+15	11	XXXXXXXXXXXX
0.6750001E+15	7	XXXXXXX
0.9450001E+15	4	XXXX
0.1215000E+16	4	XXXX
0.1485000E+16	3	XXX
0.1755000E+16	3	XXX
0.2025000E+16	1	X
0.2295000E+16	3	XXX
0.2565001E+16	1	X
0.2835001E+16	2	XX
0.3105001E+16	1	X
0.3375001E+16	1	X
0.3645001E+16	2	XX
0.3915001E+16	1	X
0.4185002E+16	1	X
0.4455002E+16	1	X
0.4725002E+16	1	X
0.4995002E+16	1	X
0.5265002E+16	0	
0.5535002E+16	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.5950341E+14	0.5433227E+16	0.5373723E+16	0.1202509E+16	0.5745110E+15	0.19

HISTOGRAM FOR VARIABLE NO. 13 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
-7.980001	1	X
-7.700001	1	X
-7.420001	2	XX
-7.140000	2	XX
-6.860000	1	X
-6.580000	5	XXXXX
-6.300000	9	XXXXXXXXXX
-6.020000	9	XXXXXXXXXX
-5.739999	10	XXXXXXXXXX
-5.459999	10	XXXXXXXXXX
-5.179999	8	XXXXXXXXXX
-4.899999	10	XXXXXXXXXX
-4.619998	0	
-4.339998	1	X
-4.059998	1	X
-3.779998	0	
-3.499998	1	X
-3.219998	1	X
-2.939998	1	X
-2.659998	0	
-2.379998	2	XX
	75	

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-7.930552	-2.311468	5.619084	-5.605802	-5.680040	1.0

HISTOGRAM FOR VARIABLE NO. 14 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
-12.42000	1	X
-12.06000	1	X
-11.70000	1	X
-11.34000	1	X
-10.98000	1	X
-10.62000	1	X
-10.26000	1	X
-9.900001	2	XX
-9.540001	1	X
-9.180001	1	X

-8.820002	5	XXXXX
-8.460002	5	XXXXX
-8.100002	5	XXXXX
-7.740002	5	XXXXX
-7.380002	5	XXXXX
-7.020002	4	XXXX
-6.660002	5	XXXXX
-6.300002	8	XXXXXXXXXX
-5.940001	7	XXXXXXXXXX
-5.580001	8	XXXXXXXXXX
-5.220001	7	XXXXXXXXXX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-12.25908	-5.048095	7.210989	-7.399879	-7.033592	3.2

HISTOGRAM FOR VARIABLE NO. 15 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
-8.745000	1	X
-8.415000	3	XXX
-8.085000	4	XXXX
-7.755000	3	XXX
-7.425000	4	XXXX
-7.095000	2	XX
-6.765000	4	XXXX
-6.435000	3	XXX
-6.105000	3	XXX
-5.775001	3	XXX
-5.445001	3	XXX
-5.115001	4	XXXX
-4.785001	2	XX
-4.455001	4	XXXX
-4.125001	2	XX
-3.795001	4	XXXX
-3.465001	3	XXX
-3.135001	5	XXXXX
-2.805001	7	XXXXXXXXXX
-2.475001	5	XXXXX
-2.145001	6	XXXXXX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-8.595756	-2.010489	6.585267	-4.991785	-4.790796	4.2

HISTOGRAM FOR VARIABLE NO. 16 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
0.6239996E-01	1	X
0.7199995E-01	1	X
0.8159994E-01	0	
0.9119993E-01	2	XX
0.1007999	6	XXXXXX
0.1103999	5	XXXXX
0.1199999	12	XXXXXXXXXXXX
0.1295999	5	XXXXX
0.1391999	6	XXXXXX
0.1487999	5	XXXXX
0.1583999	8	XXXXXXXX
0.1679999	4	XXXX
0.1775999	9	XXXXXXXXXX
0.1871999	2	XX
0.1967999	1	X
0.2063999	5	XXXXX
0.2159999	1	X
0.2255999	0	
0.2351999	1	X
0.2447999	0	
0.2543999	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.5809073E-01	0.2498642	0.1917735	0.1468146	0.1439133	0.14

HISTOGRAM FOR VARIABLE NO. 17 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
22.00000	1	X
26.00000	7	XXXXXXXX
30.00000	7	XXXXXXXX
34.00000	6	XXXXXX
38.00000	5	XXXXX
42.00000	4	XXXX
46.00000	2	XX
50.00000	4	XXXX
54.00000	2	XX
58.00000	5	XXXXX
62.00000	4	XXXX
65.99999	2	XX
69.99999	3	XXX

73.99999	2	XX
77.99999	3	XXX
81.99999	4	XXXX
85.99999	3	XXX
89.99999	3	XXX
93.99999	3	XXX
97.99999	3	XXX
102.0000	2	XX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
23.37967	103.3688	79.98914	57.02769	55.78229	582

HISTOGRAM FOR VARIABLE NO. 18 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
2.299999	3	XXX
6.899998	4	XXXX
11.50000	13	XXXXXXXXXXXXXXXX
16.09999	3	XXX
20.69999	2	XX
25.29999	2	XX
29.89999	5	XXXXX
34.49999	3	XXX
39.09999	3	XXX
43.69999	3	XXX
48.29998	7	XXXXXXX
52.89998	3	XXX
57.49998	3	XXX
62.09998	2	XX
66.69998	2	XX
71.29998	3	XXX
75.89998	3	XXX
80.49998	2	XX
85.09998	1	X
89.69997	5	XXXXX
94.29997	3	XXX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
1.497821	94.20219	92.70438	42.20030	40.65907	796

HISTOGRAM FOR VARIABLE NO. 19 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
0.4200000E-01	6	XXXXXX

0.7000001E-01	0	
0.9800001E-01	4	XXXX
0.1260000	0	
0.1540000	6	XXXXXX
0.1820000	5	XXXXX
0.2100000	5	XXXXX
0.2380000	12	XXXXXXXXXXXX
0.2660000	5	XXXXX
0.2940000	5	XXXXX
0.3220000	0	
0.3500000	5	XXXXX
0.3780000	6	XXXXXX
0.4060000	0	
0.4340000	6	XXXXXX
0.4620000	0	
0.4900000	0	
0.5180000	0	
0.5460000	5	XXXXX
0.5740000	0	
0.6020000	5	XXXXX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.5080000E-01	0.6096000	0.5588000	0.2934133	0.2508300	0.23

HISTOGRAM FOR VARIABLE NO. 20 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
0.9750000	23	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
1.1250000	0	
1.2750000	0	
1.4250000	0	
1.5750000	0	
1.7250000	0	
1.8750000	0	
2.0250000	10	XXXXXXXXXX
2.1750000	0	
2.3250000	0	
2.4750000	0	
2.6250000	0	
2.7750000	0	
2.9250000	16	XXXXXXXXXXXXXXXXXXXX
3.0750001	0	
3.2250001	0	

3.375001	0				
3.525001	0				
3.675001	0				
3.825001	0				
3.975001	26	XXXXXXXXXXXXXXXXXXXXXXXXXXXX			
	75				
MIN	MAX	RANGE	MEAN	MEDIAN	VAR
1.000000	4.000000	3.000000	2.600000	3.000000	1.5

HISTOGRAM FOR VARIABLE NO. 21 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.				
-8.750003	9	XXXXXXXXXX			
-6.250002	0				
-3.750002	0				
-1.250001	0				
1.250000	10	XXXXXXXXXX			
3.750000	0				
6.250001	0				
8.750002	20	XXXXXXXXXXXXXXXXXXXXXXXXXX			
11.25000	0				
13.75000	0				
16.25000	0				
18.75000	0				
21.25000	0				
23.75000	11	XXXXXXXXXXXX			
26.25000	0				
28.75000	0				
31.25000	0				
33.75000	11	XXXXXXXXXXXX			
36.25000	0				
38.75000	14	XXXXXXXXXXXXXXXX			
	75				
MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-10.00000	40.00000	50.00000	17.02667	8.000000	285

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RAW

1	1.0000						
2	-0.0032	1.0000					
3	0.9989	0.0019	1.0000				
4	-0.0092	-0.0049	-0.0089	1.0000			
5	0.1866	0.4724	0.1932	0.1200	1.0000		
6	-0.0006	-0.0854	-0.0086	0.6445	-0.0410	1.0000	
7	-0.0444	-0.0011	-0.0442	0.0065	-0.0789	-0.0746	1.0000

8	-0.0145	0.0228	-0.0149	0.0453	-0.1155	0.1400	0.5860	1.0000		
9	0.0355	-0.0039	0.0359	-0.0253	-0.1721	0.1551	0.5991	0.5854	1.0000	
10	-0.0674	-0.0364	-0.0707	-0.0522	-0.0289	-0.0377	-0.1039	-0.0414	-0.0494	1.
11	-0.0284	0.0467	-0.0337	-0.1098	-0.0345	-0.0540	0.0512	0.0634	0.0174	0.
12	0.0034	-0.0143	0.0110	-0.0599	-0.1400	-0.0680	-0.0872	-0.0197	-0.0227	-0.
13	0.0000	0.0032	-0.0005	0.1273	-0.0830	-0.0104	-0.0333	-0.0557	-0.0727	-0.
14	0.0378	-0.0254	0.0321	0.0447	-0.0911	0.0487	0.0180	0.0273	0.0140	-0.
15	0.0023	0.0020	0.0005	-0.1283	-0.0367	-0.1504	0.0331	-0.0109	0.0029	-0.
16	0.0153	-0.0096	0.0187	0.0245	-0.1840	-0.1111	0.0328	0.0056	-0.0213	0.
17	0.0167	0.0024	0.0206	-0.0950	-0.1932	-0.0936	-0.0510	0.0257	-0.0330	0.
18	0.0132	-0.0157	0.0152	0.0210	-0.0703	-0.1367	-0.0055	0.0364	0.0380	0.
19	0.0403	-0.0042	0.0394	0.0418	-0.1963	0.1154	-0.0661	-0.0373	-0.0532	0.
20	-0.0254	-0.0230	-0.0279	-0.0535	-0.0455	0.0306	-0.0103	0.0427	0.0327	0.
21	-0.0372	0.0278	-0.0343	-0.1442	-0.0818	-0.0823	0.0023	-0.0307	-0.0256	-0.
	1	2	3	4	5	6	7	8	9	

VARIABLES

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RAW

16	1.0000									
17	0.0187	1.0000								
18	0.0070	0.0301	1.0000							
19	0.0409	-0.0216	0.0478	1.0000						
20	0.0122	0.0311	0.0285	0.1002	1.0000					
21	0.0378	-0.0171	-0.0212	0.0407	0.0773	1.0000				
	16	17	18	19	20	21				

VARIABLES

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RANK

1	1.0000									
2	-0.0330	1.0000								
3	0.9990	-0.0300	1.0000							
4	-0.0212	0.0265	-0.0190	1.0000						
5	-0.0226	0.9431	-0.0168	0.0129	1.0000					
6	-0.0075	0.1110	-0.0110	0.7785	0.0576	1.0000				
7	-0.0305	-0.0233	-0.0269	-0.0141	-0.0106	0.0150	1.0000			
8	-0.0094	0.0119	-0.0075	0.0164	-0.0033	-0.0195	0.5857	1.0000		
9	0.0257	0.0081	0.0263	-0.0108	0.0068	-0.0449	0.5976	0.5861	1.0000	
10	-0.0148	-0.0252	-0.0170	0.0013	0.0096	-0.0424	-0.0395	0.0313	0.0040	1.
11	0.0360	-0.0192	0.0335	-0.0059	-0.0027	0.0014	0.0008	0.0449	0.0149	0.
12	0.0193	0.0008	0.0272	0.0008	-0.0272	-0.0264	-0.0037	0.0228	0.0154	-0.
13	0.0262	-0.0368	0.0312	-0.0038	-0.0404	0.0072	-0.0003	0.0418	-0.0031	-0.
14	0.0539	0.0170	0.0487	0.0165	0.0042	0.0105	0.0190	-0.0316	-0.0072	-0.
15	-0.0229	0.0152	-0.0222	-0.0282	0.0178	0.0372	0.0333	-0.0026	0.0161	-0.
16	-0.0012	0.0158	0.0005	0.0128	0.0275	-0.0166	0.0230	0.0040	-0.0376	0.

17	0.0368	0.0388	0.0358	0.0733	0.0333	0.0609	-0.0328	0.0366	-0.0205	-0.
18	0.0091	0.0424	0.0107	-0.0183	0.0667	-0.0438	-0.0078	0.0077	0.0323	0.
19	0.0478	0.0078	0.0463	0.0283	0.0388	0.0093	-0.0535	-0.0578	-0.0578	0.
20	-0.0033	-0.0189	-0.0050	0.0103	-0.0432	-0.0556	0.0023	0.0570	0.0418	-0.
21	-0.0169	0.0076	-0.0145	-0.0182	-0.0220	-0.0600	-0.0037	-0.0319	0.0005	0.
	1	2	3	4	5	6	7	8	9	

VARIABLES

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RANK

16	1.0000									
17	0.0657	1.0000								
18	0.0173	0.0235	1.0000							
19	0.0726	0.0015	0.0455	1.0000						
20	-0.0085	0.0171	0.0172	0.0347	1.0000					
21	0.0388	-0.0084	-0.0329	0.0245	0.0663	1.0000				
	16	17	18	19	20	21				

VARIABLES

OUTPUT FILE FOR LHS TEST 2

RANDOM SEED = 933090934

NUMBER OF VARIABLES = 21

NUMBER OF OBSERVATIONS = 200

THE SAMPLE INPUT VECTORS WILL BE PRINTED ALONG WITH THEIR CORRESPONDING RANKS

HISTOGRAMS OF THE ACTUAL SAMPLE WILL BE PLOTTED FOR EACH INPUT VARIABLE

THE CORRELATION MATRICES (RAW DATA AND RANK CORRELATIONS) WILL BE PRINTED

VARIABLE	DISTRIBUTION	RANGE	LABEL		
1	NORMAL	0.0000E+00 TO 0.2000	GLOBAL	DISPPERC	
2	NORMAL	577.0 TO 1042.	WEP203	QRF M2CS	
3	NORMAL	-3.6737E-02 TO 8.3264E-02	WEP203	QRF M2TC	
4	LOGNORMAL	1.0000E-02 TO 2.130	TESTMAT1	TESTPRP1	
5	LOGNORMAL	1.0000E-03 TO 3.450	TESTMAT2	TESTPRP2	
6	LOGNORMAL	1.0000E-04 TO 5.250	TESTMAT3	TESTPRP3	
7	UNIFORM	-0.5000 TO 0.5000	CANISTER	EFFCAREA	
8	UNIFORM	0.0000E+00 TO 1.000	CANISTER	BACFRC	
9	UNIFORM	12.50 TO 500.0	PU	KDFE	
10	LOGUNIFORM	1.0000E-17 TO 1.0000E-11	GCERAMIC	CORATEOX	
11	LOGUNIFORM	1.0000E-06 TO 1000.	CANISTER	EFFDAREA	
12	LOGUNIFORM	5.6000E+13 TO 5.6000E+15	IN825	CORATEOX	
13	USER SUPPLIED DISTRIBUTION		(CUMULATIVE)	NP	
14	USER SUPPLIED DISTRIBUTION		(CUMULATIVE)	PU	
15	USER SUPPLIED DISTRIBUTION		(CUMULATIVE)	U	
16	USER SUPPLIED DISTRIBUTION		(DATA)	Culebra	Por
17	USER SUPPLIED DISTRIBUTION		(DATA)	TESTMAT1	TES
18	USER SUPPLIED DISTRIBUTION		(DATA)	TESTMAT2	TES

19	USER SUPPLIED DISTRIBUTION	(DELTA)	BOREHOLE	D
20	USER SUPPLIED DISTRIBUTION	(DELTA)	DRZ 0	R
21	USER SUPPLIED DISTRIBUTION	(DELTA)	S HALITE	G

LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(1)	X(2)	X(3)	X(4)	X(5)	X(6)	X(7)
1	1.235E-01	1.042E+03	-3.674E-02	9.992E-02	3.618E-02	3.374E-02	-7.274E-0
2	6.190E-02	6.652E+02	3.490E-02	3.209E-02	1.001E-01	1.585E-03	-2.251E-0
3	5.547E-02	9.072E+02	1.724E-02	1.762E-01	1.377E-02	2.227E-03	1.747E-0
4	8.605E-02	7.613E+02	-2.449E-02	2.689E-01	5.811E-02	4.993E-04	-3.674E-0
5	1.108E-01	7.199E+02	2.987E-02	3.008E-01	1.495E-01	1.493E-01	4.474E-0
6	8.892E-02	6.929E+02	2.568E-02	2.241E-02	4.505E-02	1.000E-04	4.521E-0
7	8.076E-02	7.488E+02	2.317E-02	4.905E-02	1.251E-03	1.099E-01	2.292E-0
8	1.693E-01	7.749E+02	6.951E-02	2.007E-01	1.573E-02	1.574E-01	-4.335E-0
9	1.335E-01	9.396E+02	8.326E-02	2.729E-01	2.825E-01	8.356E-03	1.921E-0
10	8.934E-02	7.115E+02	3.041E-02	2.213E-01	1.523E-01	3.800E+00	-5.883E-0
11	5.151E-02	1.035E+03	-2.745E-02	2.922E-01	9.953E-01	4.846E-01	4.259E-0
12	1.447E-01	7.866E+02	3.694E-02	8.817E-02	7.530E-03	3.345E-01	-4.470E-0
13	8.524E-02	8.739E+02	2.120E-02	3.339E-02	3.126E-01	2.323E-03	4.977E-0
14	1.331E-01	8.486E+02	3.230E-02	2.418E-01	8.887E-02	3.022E-01	4.097E-0
15	6.962E-02	7.719E+02	3.108E-02	8.954E-02	2.113E-02	1.357E-02	7.379E-0
16	9.675E-02	7.505E+02	1.226E-02	4.067E-02	1.015E-01	5.941E-03	-3.643E-0
17	7.054E-02	7.633E+02	2.651E-02	1.389E-01	1.151E-01	1.015E-02	-3.102E-0
18	1.199E-01	8.083E+02	8.326E-02	1.032E-01	1.931E-02	5.121E-03	-4.198E-0
19	7.627E-02	7.297E+02	1.785E-02	1.126E-01	8.170E-03	3.043E-02	-3.496E-0
20	9.095E-02	7.174E+02	2.273E-02	7.000E-02	2.378E-01	1.534E-02	-1.518E-0
21	1.144E-01	7.343E+02	-4.114E-03	1.673E-01	2.036E-01	2.391E-02	-3.741E-0
22	8.160E-02	1.042E+03	3.070E-02	3.785E-02	2.532E-01	2.121E-03	-2.484E-0
23	7.562E-02	8.286E+02	5.388E-02	3.674E-02	4.205E-03	5.192E-01	3.959E-0
24	1.152E-01	7.463E+02	6.064E-03	5.809E-02	4.802E-01	4.824E-02	-4.291E-0
25	1.320E-01	1.011E+03	5.699E-02	6.466E-02	1.357E-03	3.988E-03	3.031E-0
26	9.773E-03	9.241E+02	3.157E-02	5.825E-01	1.646E-02	3.821E-04	3.797E-0
27	1.643E-02	8.060E+02	2.974E-02	2.325E-02	6.776E-02	1.007E-03	1.891E-0
28	1.317E-01	7.001E+02	3.966E-02	6.744E-02	1.166E-02	2.870E-02	1.521E-0
29	1.051E-01	8.688E+02	5.733E-02	1.082E-01	5.403E-02	4.641E-04	2.592E-0
30	1.123E-01	7.797E+02	1.532E-02	2.130E+00	1.000E-03	1.737E-03	2.878E-0
31	-2.235E-08	8.325E+02	2.846E-02	7.115E-02	6.067E-02	1.811E-02	-2.292E-0
32	9.707E-02	8.920E+02	4.596E-02	1.844E-01	4.189E-01	9.866E-03	3.887E-0
33	1.609E-01	5.890E+02	4.025E-02	1.251E+00	6.592E-03	5.785E-03	-4.590E-0
34	1.023E-01	9.153E+02	4.231E-03	3.409E-01	1.929E-01	1.276E+00	-3.997E-0
35	1.662E-01	8.875E+02	1.597E-02	1.298E+00	3.001E-02	1.558E-01	2.361E-0
36	1.114E-01	8.222E+02	5.465E-02	4.533E-02	7.660E-02	3.343E-02	4.751E-0
37	6.481E-02	8.554E+02	5.198E-02	7.100E-01	2.972E-01	6.609E-04	2.957E-0

38	1.247E-01	1.002E+03	6.418E-02	2.641E-01	3.089E-02	2.441E-04	-2.902E-0
39	1.205E-02	8.041E+02	-1.248E-03	7.416E-01	1.796E-02	9.172E-03	3.219E-0
40	1.042E-01	7.815E+02	1.979E-02	1.269E-01	1.669E-01	3.485E-03	2.440E-0
41	1.298E-01	6.253E+02	3.333E-02	2.438E-01	4.663E-02	2.571E-02	-1.525E-0
42	3.396E-02	7.834E+02	-2.558E-02	7.269E-02	1.621E+00	3.247E-02	3.055E-0
43	9.784E-02	7.940E+02	-1.133E-02	5.476E-02	3.450E+00	5.289E-02	-3.412E-0
44	1.063E-01	6.199E+02	-1.656E-02	5.055E-01	1.706E-01	4.350E-03	7.826E-0
45	1.008E-01	7.318E+02	2.757E-02	7.732E-02	2.971E-03	1.159E-01	2.078E-0
46	1.742E-01	7.653E+02	2.996E-03	3.226E-01	1.392E-02	1.126E-02	1.212E-0
47	7.847E-02	7.625E+02	3.436E-02	5.954E-02	5.993E-03	2.081E-01	-4.378E-0
48	1.045E-01	9.132E+02	2.006E-02	2.448E-02	1.496E-02	7.444E-03	1.082E-0
49	1.127E-01	8.514E+02	1.622E-02	3.942E-01	1.190E-01	7.038E-02	4.239E-0
50	1.461E-01	8.707E+02	4.241E-02	2.946E-02	6.450E-01	2.027E-02	3.043E-0
51	8.296E-02	8.011E+02	2.256E-02	2.061E-01	3.424E-02	9.235E-02	7.736E-0
52	4.772E-02	7.662E+02	-1.875E-02	6.000E-01	1.076E-01	1.918E-03	-2.216E-0
53	6.588E-02	8.221E+02	5.724E-03	1.119E-01	2.212E-02	7.784E-02	-1.854E-0
54	9.587E-02	6.732E+02	1.889E-03	6.948E-01	2.520E-03	1.937E-01	1.009E-0
55	1.511E-01	6.873E+02	2.337E-02	1.058E-01	2.458E+00	2.485E-02	-4.634E-0
56	9.176E-02	9.597E+02	3.283E-02	8.497E-02	5.265E-03	3.446E-03	-3.362E-0
57	7.959E-02	6.828E+02	3.882E-03	8.770E-02	4.180E-02	4.646E-02	1.296E-0
58	1.755E-01	8.410E+02	2.473E-02	1.222E-01	3.034E-01	2.567E-01	5.468E-0
59	5.854E-02	8.393E+02	7.869E-02	5.159E-01	5.777E-01	1.799E-01	4.729E-0
60	8.372E-02	8.309E+02	-2.901E-03	1.457E-02	2.321E-02	1.215E-01	-1.325E-0
61	1.084E-01	8.447E+02	3.821E-02	4.592E-01	7.450E-02	1.224E-02	-1.821E-0
62	2.000E-01	7.147E+02	-2.205E-03	1.632E-02	2.764E-01	7.953E-02	6.325E-0
63	2.518E-02	7.374E+02	5.557E-02	9.516E-02	1.830E-01	7.479E-04	1.514E-0
64	4.900E-02	8.857E+02	3.863E-02	5.059E-02	9.330E-02	1.606E-02	3.286E-0
65	2.150E-02	9.063E+02	4.931E-02	3.023E-02	4.551E-01	1.655E-01	1.693E-0
66	6.348E-02	8.722E+02	5.288E-02	8.456E-01	3.750E-02	1.044E-02	-2.105E-0
67	6.674E-02	7.930E+02	-3.267E-02	1.277E-02	8.493E-02	4.296E-02	-3.331E-0
68	8.188E-02	6.723E+02	6.641E-02	1.232E-01	9.800E-03	6.672E-02	-3.523E-0
69	1.116E-01	7.357E+02	3.627E-02	1.601E+00	1.752E-02	5.456E-03	4.328E-0
70	7.427E-02	8.195E+02	4.767E-02	1.591E-01	9.559E-01	2.272E-02	-1.238E-0
71	1.217E-01	6.425E+02	5.133E-03	7.992E-02	8.300E-02	1.685E-02	8.779E-0
72	1.526E-01	6.354E+02	4.030E-02	1.103E-02	5.323E-02	2.973E-02	1.420E-0
73	1.441E-01	5.770E+02	1.354E-02	1.432E-01	4.919E-02	1.305E-02	2.149E-0
74	9.912E-02	6.578E+02	4.094E-02	9.877E-02	3.289E-02	2.319E-04	3.847E-0
75	1.790E-01	9.612E+02	3.136E-02	1.102E+00	2.411E-02	1.939E-02	3.611E-0
76	1.067E-01	6.904E+02	5.168E-02	2.684E-02	3.245E-01	1.001E-01	-4.466E-0
77	7.499E-02	7.059E+02	1.910E-02	2.832E-02	8.638E-02	6.118E-03	-2.323E-0
78	1.056E-01	8.050E+02	1.440E-02	1.184E-01	9.754E-02	6.610E-03	-3.762E-0
79	7.276E-02	7.915E+02	2.439E-02	2.564E-01	7.089E-01	5.250E+00	-1.923E-0

80	5.521E-02	8.023E+02	3.737E-02	1.013E+00	2.841E-02	2.509E-03	1.123E-0
81	1.242E-01	7.958E+02	2.539E-02	4.154E-01	1.371E-01	9.290E-02	3.426E-0
82	9.239E-02	9.945E+02	2.136E-02	5.597E-02	1.805E-02	1.258E-03	-1.409E-0
83	6.796E-02	9.415E+02	-1.288E-02	2.123E-01	3.968E-02	6.253E-02	2.756E-0
84	4.628E-02	7.433E+02	-3.674E-02	1.898E-01	4.980E-02	1.322E-04	-4.117E-0
85	1.494E-01	8.462E+02	8.566E-03	6.649E-01	6.321E-02	4.034E-04	-3.314E-0
86	6.024E-02	8.828E+02	4.365E-02	1.725E-01	6.182E-02	2.964E-03	-4.890E-0
87	3.778E-02	9.503E+02	3.417E-02	2.468E-01	3.693E-01	1.252E-01	-1.752E-0
88	1.681E-01	7.285E+02	-2.161E-02	4.016E-01	3.786E-02	6.461E-01	-2.411E-0
89	1.276E-01	8.470E+02	2.863E-02	8.187E-02	6.025E-01	2.317E-01	-4.646E-0
90	1.037E-01	7.187E+02	1.674E-02	8.625E-02	8.397E-01	3.073E-04	-4.039E-0
91	9.325E-02	7.065E+02	4.306E-02	3.498E-02	3.526E-03	6.452E-02	-8.943E-0
92	1.231E-01	8.893E+02	3.659E-02	1.013E-01	4.036E-03	5.750E-02	2.657E-0
93	1.354E-01	8.361E+02	1.375E-02	1.636E-01	1.928E+00	1.384E-01	2.464E-0
94	-2.235E-08	7.775E+02	2.720E-02	3.459E-01	4.334E-02	4.750E-03	9.732E-0
95	3.542E-02	7.473E+02	1.328E-02	2.294E-01	2.638E-02	5.358E-02	-6.405E-0
96	6.127E-02	8.938E+02	7.021E-03	3.301E-02	4.789E-03	1.954E-01	-4.910E-0
97	7.343E-02	6.045E+02	1.185E-02	5.563E-01	7.218E-02	1.312E-02	-3.832E-0
98	5.650E-02	6.957E+02	7.636E-04	6.427E-01	3.450E+00	3.770E-03	1.452E-0
99	1.224E-01	8.734E+02	1.077E-02	1.000E-02	5.538E-02	1.839E-02	-1.340E-0
100	1.307E-01	8.113E+02	5.093E-02	1.046E+00	3.267E-02	7.695E-03	2.160E-0
101	8.041E-02	9.315E+02	7.010E-02	3.900E-01	2.062E-02	4.091E-02	5.814E-0
102	8.683E-02	7.754E+02	-3.238E-03	5.222E-02	2.584E-01	5.539E-04	3.350E-0
103	1.501E-01	9.365E+02	4.406E-02	1.098E-01	7.997E-02	2.650E-03	-4.419E-0
104	7.487E-02	8.539E+02	3.516E-02	1.339E-01	3.638E-03	5.250E+00	1.615E-0
105	1.089E-01	8.198E+02	3.203E-02	7.637E-02	8.174E-01	6.822E-03	-2.501E-0
106	7.712E-02	7.223E+02	2.922E-02	2.337E-01	2.295E-03	3.602E-02	2.320E-0
107	9.276E-02	7.588E+02	4.200E-02	2.550E-02	9.500E-02	1.764E-03	4.812E-0
108	1.365E-01	6.488E+02	-5.608E-03	1.600E-01	2.075E-03	4.256E-02	2.012E-0
109	1.620E-01	9.464E+02	-6.902E-03	1.327E-01	1.242E-02	1.527E+00	4.857E-0
110	1.169E-01	8.241E+02	1.871E-02	1.141E-01	1.889E-02	3.906E-02	-4.201E-0
111	7.127E-02	7.582E+02	1.882E-02	1.251E-01	1.171E-01	1.120E-02	-9.182E-0
112	1.102E-01	7.979E+02	1.749E-02	3.281E-01	3.892E-02	3.921E-03	3.596E-0
113	8.493E-02	7.825E+02	4.984E-02	8.789E-01	1.627E-01	4.470E-02	-3.932E-0
114	1.077E-01	7.785E+02	7.608E-02	1.705E-02	6.900E-03	7.174E-01	-2.180E-0
115	7.170E-02	1.023E+03	4.735E-02	3.304E-01	4.536E-03	5.667E-03	4.591E-0
116	2.263E-02	8.415E+02	9.656E-03	1.365E-01	1.550E-02	2.209E+00	-1.724E-0
117	8.268E-02	7.686E+02	5.019E-02	7.387E-02	1.552E-01	3.727E-01	-2.836E-0
118	1.597E-01	7.531E+02	4.832E-02	1.871E-01	1.049E-01	8.005E-03	2.506E-0
119	2.771E-02	7.334E+02	-1.016E-02	4.457E-01	3.589E-02	1.113E+00	3.463E-0
120	1.194E-01	8.580E+02	1.112E-02	9.253E-02	8.107E-02	1.744E-02	-1.609E-0
121	1.260E-01	8.267E+02	-9.074E-03	8.267E-02	1.973E-01	2.864E-01	4.503E-0

122	9.359E-02	8.320E+02	1.034E-02	3.762E-01	1.718E-01	4.047E-01	-4.837E-0
123	8.718E-02	7.016E+02	-1.577E-02	1.802E-01	1.372E+00	9.860E-02	3.923E-0
124	1.352E-01	8.375E+02	3.538E-02	3.794E-01	6.580E-02	8.381E-04	-6.502E-0
125	4.953E-02	6.006E+02	5.313E-02	3.976E-02	4.248E-01	1.777E-01	-2.749E-0
126	1.559E-01	8.562E+02	-1.980E-02	6.138E-02	1.332E-01	1.110E-01	3.958E-0
127	7.774E-02	8.807E+02	1.966E-02	1.797E+00	1.122E-01	5.562E-01	-4.652E-0
128	1.343E-01	9.124E+02	2.361E-02	3.517E-01	4.018E-01	2.863E-03	-1.264E-0
129	9.531E-02	7.708E+02	3.769E-02	1.406E-01	1.060E-02	1.257E-02	-9.856E-0
130	5.728E-02	8.608E+02	5.895E-02	1.451E-01	2.674E-02	2.809E-02	4.656E-0
131	6.833E-02	7.871E+02	4.341E-02	2.032E-01	2.654E-01	4.795E-02	4.409E-0
132	4.504E-02	9.041E+02	2.081E-02	1.519E-01	6.375E-03	1.416E-03	-3.247E-0
133	3.872E-02	9.498E+02	6.453E-02	4.243E-01	1.306E-02	3.915E-01	-4.764E-0
134	1.427E-01	9.537E+02	-1.347E-02	2.352E-01	1.676E-02	9.732E-04	-3.292E-0
135	1.430E-01	7.955E+02	-2.178E-04	4.424E-02	1.000E-03	5.929E-01	-3.557E-0
136	8.800E-02	8.975E+02	-3.501E-02	4.107E-02	1.815E-03	1.427E-01	3.730E-0
137	1.141E-01	9.196E+02	1.125E-02	1.646E-01	4.608E-02	2.258E+00	4.104E-0
138	1.383E-01	8.099E+02	2.796E-03	2.174E-01	4.036E-02	1.936E-03	3.504E-0
139	1.415E-01	7.986E+02	-7.101E-03	8.029E-01	2.882E-02	1.436E-02	2.714E-0
140	3.026E-02	8.839E+02	8.320E-02	2.504E-01	1.418E+00	4.391E-01	2.377E-0
141	9.870E-02	8.526E+02	6.502E-03	4.523E-01	2.083E-01	8.444E-02	-1.654E-0
142	1.971E-01	8.999E+02	1.511E-03	2.160E-01	9.010E-02	1.132E-03	-1.177E-0
143	6.977E-02	7.083E+02	2.193E-02	4.888E-01	6.437E-02	5.098E-02	-2.236E-0
144	9.976E-02	9.096E+02	-6.137E-03	7.934E-01	3.793E-01	3.751E-02	-4.974E-0
145	9.798E-02	7.257E+02	2.500E-02	9.775E-02	6.610E-01	4.576E-03	8.259E-0
146	1.286E-01	9.866E+02	2.227E-02	1.168E-01	1.169E+00	1.542E-03	-2.667E-0
147	9.005E-02	8.771E+02	-3.926E-03	6.510E-02	3.451E-01	9.480E-03	-4.507E-0
148	4.048E-02	8.370E+02	-1.698E-02	1.043E-01	1.299E-02	1.500E-02	1.164E-0
149	9.425E-02	8.145E+02	4.887E-02	5.377E-02	1.990E-02	1.053E-01	3.315E-0
150	1.375E-01	7.885E+02	4.686E-02	1.307E-01	2.363E-02	6.440E-03	4.872E-0
151	1.388E-01	7.440E+02	3.394E-03	1.781E-01	2.750E-02	3.473E-02	2.237E-0
152	1.266E-01	6.677E+02	-3.689E-04	2.605E-01	9.163E-03	3.376E-01	-2.082E-0
153	5.301E-02	9.246E+02	4.482E-02	1.465E-01	1.210E-02	2.677E-02	6.780E-0
154	4.136E-02	8.127E+02	-1.436E-02	5.666E-02	5.055E-02	2.367E-03	1.284E-0
155	1.028E-01	8.172E+02	6.132E-02	3.162E-01	1.255E-01	8.649E-03	-2.772E-0
156	1.255E-01	9.207E+02	2.055E-02	9.656E-01	5.680E-02	8.078E-02	1.780E-0
157	1.000E-01	8.625E+02	4.003E-04	4.296E-02	6.929E-02	1.331E-01	-1.990E-0
158	1.401E-01	8.253E+02	5.967E-02	1.981E-01	7.427E-01	2.369E-01	-4.078E-0
159	1.093E-01	8.794E+02	1.566E-02	1.000E-02	1.225E-01	9.901E-01	3.663E-0
160	4.414E-02	7.415E+02	6.198E-02	1.490E-01	7.059E-02	2.878E+00	-7.831E-0
161	5.958E-02	9.751E+02	7.255E-03	3.023E-01	1.443E-02	1.811E-04	-1.094E-0
162	1.471E-01	9.834E+02	-2.253E-02	4.708E-01	4.282E-02	7.279E-02	-2.615E-0
163	3.146E-02	8.768E+02	1.647E-02	4.352E-02	2.144E-01	5.984E-02	3.135E-0

164	1.573E-01	7.139E+02	2.405E-02	2.130E+00	5.199E-01	7.436E-02	-2.973E-0
165	2.000E-01	8.677E+02	-4.869E-03	6.323E-02	9.261E-03	8.105E-01	-3.164E-0
166	7.907E-02	7.401E+02	3.363E-02	1.556E-01	7.468E-03	1.878E-02	-2.385E-0
167	4.320E-02	8.151E+02	-9.000E-03	1.205E-01	1.017E-02	3.126E-02	-2.686E-0
168	1.132E-01	7.896E+02	9.854E-03	6.232E-01	5.443E-01	9.462E-01	4.917E-0
169	1.281E-01	7.671E+02	7.184E-02	4.294E-01	4.822E-01	3.866E-02	-2.564E-0
170	6.408E-02	8.648E+02	1.276E-02	1.689E-01	5.397E-03	2.220E-01	-1.380E-0
171	1.535E-01	9.707E+02	2.617E-02	4.857E-02	2.522E-02	5.631E-02	-2.025E-0
172	1.017E-01	9.331E+02	8.937E-03	1.891E-02	2.963E-02	3.115E-03	-5.126E-0
173	1.924E-01	8.917E+02	6.736E-02	6.662E-02	1.765E-01	4.928E-03	-4.739E-0
174	1.014E-01	8.964E+02	-1.087E-02	2.770E-01	1.865E-01	8.900E-04	9.200E-0
175	6.726E-02	8.655E+02	-1.363E-03	6.851E-02	5.189E-02	6.741E-04	-2.857E-0
176	1.835E-01	7.237E+02	1.248E-02	1.950E-01	1.068E-02	1.343E-03	-3.861E-0
177	1.156E-01	8.281E+02	1.482E-02	1.551E+00	4.772E-02	1.631E-02	4.359E-0
178	1.206E-01	6.761E+02	1.806E-02	1.287E-01	1.455E-01	2.730E-03	-1.470E-0
179	9.513E-02	8.344E+02	3.317E-02	3.595E-01	1.426E-01	1.676E+00	2.929E-0
180	1.716E-01	7.727E+02	4.152E-02	1.948E-02	8.529E-03	1.219E-03	-1.566E-0
181	1.175E-01	7.549E+02	3.911E-02	6.023E-02	5.921E-02	8.658E-02	1.384E-0
182	5.189E-02	7.854E+02	-7.922E-03	2.271E-01	2.262E-02	1.063E-02	-8.416E-0
183	1.548E-01	6.793E+02	4.668E-03	1.831E-01	2.541E-02	1.000E-04	4.636E-0
184	1.881E-01	8.168E+02	5.569E-02	2.816E-01	1.350E-01	2.788E-01	-1.021E-0
185	1.577E-01	8.080E+02	8.005E-03	2.871E-01	7.484E-02	3.212E-03	1.328E-0
186	1.402E-01	9.293E+02	2.162E-03	7.480E-02	3.192E-02	2.079E-02	-9.535E-0
187	6.233E-02	7.524E+02	9.059E-03	1.540E-01	1.123E+00	2.672E-01	2.897E-0
188	1.184E-01	6.307E+02	6.254E-02	3.552E-02	3.441E-02	4.132E-03	2.624E-0
189	5.375E-02	6.522E+02	3.579E-02	3.108E-01	5.663E-03	2.114E-02	1.965E-0
190	9.076E-02	8.432E+02	4.507E-02	4.691E-02	1.063E-01	2.591E-02	4.036E-0
191	1.162E-01	6.585E+02	7.682E-03	9.140E-02	2.205E-01	8.754E-03	4.175E-0
192	1.293E-01	8.005E+02	5.856E-02	3.659E-01	8.476E-03	2.342E-02	-1.137E-0
193	6.067E-03	5.770E+02	3.893E-02	5.428E-01	2.308E-01	2.172E-02	-3.879E-0
194	1.071E-01	8.504E+02	4.554E-02	5.265E-01	1.287E-01	6.179E-02	-3.085E-0
195	8.427E-02	6.851E+02	2.784E-02	9.470E-02	1.126E-02	7.709E-01	2.821E-0
196	1.638E-01	7.560E+02	4.140E-02	5.120E-02	3.046E+00	1.170E-02	4.275E-0
197	8.768E-02	6.985E+02	1.408E-02	5.683E-01	3.024E-03	4.418E-03	3.153E-0
198	1.478E-01	8.605E+02	2.883E-02	7.916E-02	2.448E-01	7.275E-03	1.564E-0
199	1.181E-01	9.022E+02	2.639E-02	2.103E-01	2.151E-02	7.087E-03	-3.040E-0
200	1.209E-01	9.684E+02	2.699E-02	2.115E-02	3.507E-01	1.410E-02	1.843E-0

LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(11)	X(12)	X(13)	X(14)	X(15)	X(16)	X(17)
1	3.592E-02	1.311E+15	-5.777E+00	-7.762E+00	-8.284E+00	6.991E-02	5.797E+0
2	1.061E-04	1.501E+15	-5.451E+00	-6.320E+00	-7.122E+00	1.618E-01	8.955E+0
3	4.793E-02	3.171E+14	-6.057E+00	-7.623E+00	-6.011E+00	1.042E-01	4.328E+0

4	6.679E-01	1.164E+15	-6.369E+00	-8.668E+00	-5.054E+00	1.711E-01	6.871E+0
5	3.410E-02	1.193E+15	-2.779E+00	-7.715E+00	-6.151E+00	2.075E-01	5.600E+0
6	1.990E+01	1.595E+14	-5.036E+00	-8.998E+00	-8.391E+00	1.420E-01	3.158E+0
7	3.548E-01	3.656E+14	-3.977E+00	-6.594E+00	-5.859E+00	1.126E-01	6.246E+0
8	1.502E-03	1.985E+15	-3.762E+00	-6.626E+00	-4.764E+00	1.238E-01	9.884E+0
9	2.087E-03	7.113E+14	-5.860E+00	-6.710E+00	-3.361E+00	1.973E-01	2.346E+0
10	1.066E+00	1.824E+15	-5.243E+00	-6.771E+00	-4.188E+00	1.791E-01	2.463E+0
11	1.364E+01	3.292E+15	-4.846E+00	-8.212E+00	-4.706E+00	1.448E-01	8.226E+0
12	1.249E-05	1.190E+14	-6.191E+00	-7.259E+00	-7.343E+00	1.822E-01	2.893E+0
13	1.540E-06	6.855E+14	-7.203E+00	-7.740E+00	-3.057E+00	1.244E-01	7.310E+0
14	6.150E+01	2.030E+14	-6.580E+00	-6.951E+00	-3.530E+00	1.293E-01	6.112E+0
15	4.875E-05	4.106E+14	-4.979E+00	-6.542E+00	-6.387E+00	1.140E-01	8.398E+0
16	1.923E+02	3.788E+14	-4.826E+00	-7.642E+00	-6.056E+00	1.781E-01	2.814E+0
17	6.938E+00	1.099E+15	-7.747E+00	-7.350E+00	-4.860E+00	1.206E-01	7.136E+0
18	2.356E+02	5.568E+15	-7.857E+00	-1.194E+01	-3.868E+00	2.047E-01	5.563E+0
19	3.333E+02	6.646E+13	-4.805E+00	-7.772E+00	-6.024E+00	1.625E-01	9.767E+0
20	1.406E+02	4.467E+14	-5.837E+00	-1.175E+01	-5.125E+00	1.780E-01	3.360E+0
21	5.488E+02	9.590E+13	-7.683E+00	-7.557E+00	-2.570E+00	1.273E-01	5.896E+0
22	5.905E+01	1.853E+14	-6.565E+00	-5.147E+00	-5.803E+00	1.190E-01	3.068E+0
23	3.562E-06	7.662E+14	-6.151E+00	-7.895E+00	-7.795E+00	1.259E-01	4.632E+0
24	3.414E-05	9.439E+13	-5.215E+00	-7.609E+00	-4.921E+00	1.287E-01	5.356E+0
25	1.927E-04	4.139E+15	-4.856E+00	-7.470E+00	-7.786E+00	2.034E-01	4.799E+0
26	4.022E-04	3.796E+15	-6.246E+00	-5.762E+00	-7.226E+00	9.583E-02	9.149E+0
27	2.981E-03	5.081E+14	-3.622E+00	-7.851E+00	-8.144E+00	2.513E-01	5.963E+0
28	1.081E-05	5.973E+14	-6.037E+00	-7.250E+00	-7.198E+00	2.192E-01	9.271E+0
29	1.822E-01	2.468E+15	-6.226E+00	-8.444E+00	-3.734E+00	2.150E-01	1.007E+0
30	9.620E-02	2.930E+15	-6.528E+00	-1.234E+01	-4.812E+00	1.071E-01	8.358E+0
31	2.771E+02	1.715E+14	-5.906E+00	-6.838E+00	-3.838E+00	1.595E-01	2.363E+0
32	3.279E+00	7.969E+13	-6.078E+00	-8.127E+00	-4.460E+00	2.097E-01	3.669E+0
33	1.065E-03	2.734E+14	-4.787E+00	-8.069E+00	-6.823E+00	6.133E-02	5.773E+0
34	1.250E+01	6.911E+13	-5.988E+00	-7.900E+00	-7.164E+00	2.323E-01	1.032E+0
35	2.483E-05	6.297E+14	-4.772E+00	-8.098E+00	-5.696E+00	1.453E-01	8.544E+0
36	8.916E+01	3.363E+14	-4.872E+00	-7.927E+00	-4.074E+00	1.795E-01	7.078E+0
37	8.249E-01	6.442E+13	-6.318E+00	-1.041E+01	-8.536E+00	1.227E-01	7.842E+0
38	6.494E+00	9.849E+14	-5.139E+00	-7.304E+00	-8.499E+00	1.094E-01	9.327E+0
39	3.196E-05	1.347E+14	-3.264E+00	-7.415E+00	-2.741E+00	1.097E-01	3.048E+0
40	6.754E+02	6.244E+14	-4.942E+00	-7.975E+00	-6.189E+00	1.327E-01	8.808E+0
41	6.523E-03	1.131E+14	-5.790E+00	-8.424E+00	-2.162E+00	9.898E-02	7.955E+0
42	3.438E-06	2.971E+15	-4.928E+00	-7.793E+00	-7.633E+00	1.085E-01	4.691E+0
43	3.486E-03	2.393E+15	-5.592E+00	-8.857E+00	-3.562E+00	1.109E-01	2.529E+0
44	3.910E-01	7.846E+14	-5.383E+00	-6.985E+00	-2.484E+00	1.214E-01	4.863E+0
45	2.355E-01	1.262E+15	-4.799E+00	-5.354E+00	-3.427E+00	1.692E-01	4.105E+0

46	4.314E+01	7.018E+14	-5.824E+00	-7.547E+00	-6.711E+00	1.795E-01	3.702E+0
47	2.606E-01	1.201E+14	-6.449E+00	-6.643E+00	-6.889E+00	2.037E-01	5.444E+0
48	7.744E-06	4.414E+14	-5.529E+00	-6.790E+00	-5.647E+00	9.684E-02	2.966E+0
49	9.982E+02	2.153E+14	-6.486E+00	-6.573E+00	-8.383E+00	1.274E-01	8.181E+0
50	1.640E-01	1.401E+15	-5.374E+00	-7.572E+00	-4.226E+00	1.617E-01	8.123E+0
51	2.037E-06	8.555E+14	-4.823E+00	-6.869E+00	-7.297E+00	1.054E-01	3.001E+0
52	1.079E+02	9.110E+14	-6.132E+00	-7.273E+00	-5.673E+00	1.463E-01	6.053E+0
53	1.365E-02	4.184E+15	-7.262E+00	-7.688E+00	-7.262E+00	1.894E-01	2.933E+0
54	6.048E-04	3.352E+15	-7.557E+00	-7.588E+00	-6.803E+00	8.000E-02	3.510E+0
55	2.370E-06	1.450E+15	-3.880E+00	-7.382E+00	-3.325E+00	1.279E-01	5.181E+0
56	7.366E-04	2.479E+14	-5.743E+00	-7.370E+00	-5.417E+00	1.790E-01	5.084E+0
57	8.492E-03	7.545E+14	-5.883E+00	-8.010E+00	-3.579E+00	1.617E-01	8.737E+0
58	1.866E-01	1.356E+15	-6.002E+00	-8.715E+00	-4.784E+00	1.220E-01	9.407E+0
59	3.344E-04	1.079E+14	-5.121E+00	-6.011E+00	-7.930E+00	1.438E-01	7.668E+0
60	1.273E-01	9.948E+13	-5.903E+00	-8.160E+00	-8.102E+00	8.825E-02	3.764E+0
61	4.371E-06	3.027E+15	-5.721E+00	-9.212E+00	-4.359E+00	1.784E-01	8.690E+0
62	1.260E+00	1.715E+15	-5.473E+00	-6.685E+00	-5.426E+00	1.008E-01	3.298E+0
63	7.236E-05	3.423E+15	-6.357E+00	-6.672E+00	-2.192E+00	1.638E-01	6.516E+0
64	9.565E-03	4.596E+15	-5.419E+00	-1.140E+01	-6.331E+00	1.435E-01	4.021E+0
65	7.815E-02	2.796E+15	-2.086E+00	-7.659E+00	-8.597E+00	1.787E-01	3.534E+0
66	1.512E+01	4.699E+15	-5.002E+00	-1.219E+01	-5.497E+00	1.213E-01	3.643E+0
67	2.288E-04	2.531E+14	-6.209E+00	-8.759E+00	-6.350E+00	1.456E-01	3.786E+0
68	2.055E-04	1.437E+15	-6.119E+00	-7.403E+00	-8.318E+00	1.182E-01	4.875E+0
69	1.906E-05	2.549E+15	-4.894E+00	-8.286E+00	-5.195E+00	2.255E-01	2.490E+0
70	3.280E-04	9.124E+13	-5.176E+00	-8.865E+00	-3.112E+00	9.745E-02	3.343E+0
71	2.763E-04	5.302E+14	-5.101E+00	-7.665E+00	-6.216E+00	1.793E-01	2.548E+0
72	2.349E-02	4.348E+15	-5.866E+00	-8.768E+00	-5.764E+00	1.400E-01	3.110E+0
73	1.165E-05	1.556E+14	-6.441E+00	-7.437E+00	-4.898E+00	1.769E-01	2.726E+0
74	5.145E+02	1.131E+15	-4.905E+00	-8.573E+00	-5.963E+00	1.060E-01	5.633E+0
75	1.642E-03	1.683E+14	-5.749E+00	-5.838E+00	-7.674E+00	1.405E-01	2.416E+0
76	1.166E-03	2.125E+15	-5.394E+00	-7.822E+00	-7.863E+00	1.616E-01	5.997E+0
77	9.659E-01	1.005E+14	-7.945E+00	-5.231E+00	-8.464E+00	6.382E-02	3.224E+0
78	9.315E-04	4.469E+15	-5.490E+00	-6.428E+00	-6.576E+00	1.752E-01	5.690E+0
79	9.439E-05	5.007E+15	-5.643E+00	-5.062E+00	-8.255E+00	1.784E-01	3.376E+0
80	4.229E-05	2.670E+14	-2.401E+00	-6.927E+00	-5.610E+00	1.144E-01	8.968E+0
81	4.597E+01	9.490E+14	-6.550E+00	-5.708E+00	-7.541E+00	1.409E-01	8.171E+0
82	1.252E-06	4.178E+14	-6.046E+00	-1.213E+01	-3.462E+00	1.041E-01	3.730E+0
83	1.396E-05	3.480E+15	-5.307E+00	-8.049E+00	-2.123E+00	1.782E-01	8.487E+0
84	1.137E-01	1.326E+15	-5.498E+00	-6.722E+00	-4.292E+00	2.259E-01	8.618E+0
85	8.218E-06	5.406E+14	-4.100E+00	-7.510E+00	-7.516E+00	1.549E-01	6.758E+0
86	4.583E+00	6.094E+13	-5.503E+00	-8.933E+00	-3.639E+00	1.219E-01	4.462E+0
87	1.142E+02	1.037E+14	-4.446E+00	-8.805E+00	-6.220E+00	1.223E-01	2.976E+0

88	1.572E-02	3.020E+14	-6.175E+00	-7.738E+00	-4.104E+00	1.504E-01	3.398E+0
89	2.899E+01	8.762E+13	-6.160E+00	-6.831E+00	-7.966E+00	1.756E-01	7.572E+0
90	1.851E-06	1.160E+14	-6.333E+00	-7.958E+00	-4.544E+00	1.648E-01	9.702E+0
91	3.247E+01	7.920E+14	-6.463E+00	-6.999E+00	-2.268E+00	1.204E-01	6.431E+0
92	1.140E+00	6.505E+14	-6.019E+00	-8.958E+00	-5.299E+00	1.312E-01	2.624E+0
93	6.916E+01	2.246E+15	-6.128E+00	-8.170E+00	-5.736E+00	1.228E-01	4.244E+0
94	5.317E-05	6.394E+13	-5.687E+00	-7.230E+00	-6.730E+00	1.982E-01	7.778E+0
95	5.063E-03	6.138E+14	-6.269E+00	-8.269E+00	-4.575E+00	1.459E-01	5.113E+0
96	1.875E+01	4.285E+15	-5.019E+00	-6.567E+00	-2.809E+00	1.210E-01	3.821E+0
97	1.573E-04	2.329E+14	-6.179E+00	-8.949E+00	-8.049E+00	1.617E-01	3.849E+0
98	5.298E+01	4.864E+15	-6.505E+00	-8.699E+00	-4.613E+00	1.263E-01	4.481E+0
99	4.525E-01	3.173E+15	-5.109E+00	-8.552E+00	-3.607E+00	1.786E-01	3.189E+0
100	4.401E+00	9.542E+14	-6.919E+00	-8.466E+00	-8.008E+00	8.647E-02	6.121E+0
101	3.135E-02	8.691E+14	-5.320E+00	-6.661E+00	-3.513E+00	1.676E-01	6.639E+0
102	9.117E-06	1.751E+14	-6.756E+00	-8.739E+00	-5.383E+00	1.618E-01	5.277E+0
103	4.743E-01	3.147E+15	-4.964E+00	-7.911E+00	-4.417E+00	1.066E-01	6.997E+0
104	1.341E-03	3.921E+15	-5.077E+00	-9.553E+00	-5.788E+00	1.463E-01	3.031E+0
105	3.897E-05	3.740E+15	-5.656E+00	-5.151E+00	-7.017E+00	1.196E-01	3.541E+0
106	5.441E+00	1.246E+15	-5.514E+00	-7.305E+00	-6.863E+00	1.583E-01	5.856E+0
107	5.604E-03	1.565E+15	-7.076E+00	-6.064E+00	-6.099E+00	1.345E-01	5.031E+0
108	6.191E+02	1.510E+15	-5.231E+00	-8.134E+00	-8.566E+00	1.366E-01	8.858E+0
109	2.748E-02	5.162E+14	-7.322E+00	-8.789E+00	-8.177E+00	2.071E-01	8.265E+0
110	1.414E-04	2.350E+14	-5.090E+00	-7.009E+00	-4.268E+00	1.640E-01	2.591E+0
111	1.074E-06	3.539E+14	-5.239E+00	-8.508E+00	-5.274E+00	2.052E-01	4.079E+0
112	2.094E-01	1.038E+15	-3.500E+00	-6.858E+00	-2.824E+00	2.471E-01	3.268E+0
113	1.128E+01	1.476E+14	-6.090E+00	-6.221E+00	-7.559E+00	1.617E-01	7.418E+0
114	1.517E-02	4.824E+14	-7.603E+00	-8.523E+00	-3.676E+00	1.879E-01	6.211E+0
115	7.981E-04	7.391E+13	-5.293E+00	-7.489E+00	-4.684E+00	1.390E-01	6.022E+0
116	7.946E+01	2.232E+14	-4.890E+00	-8.821E+00	-4.829E+00	1.559E-01	1.001E+0
117	4.276E-02	7.657E+13	-5.558E+00	-1.016E+01	-5.215E+00	1.234E-01	8.022E+0
118	1.828E-02	3.944E+14	-5.968E+00	-6.811E+00	-6.417E+00	7.610E-02	3.430E+0
119	6.713E-03	1.975E+14	-5.433E+00	-6.944E+00	-4.007E+00	1.230E-01	1.038E+0
120	1.030E-01	4.581E+14	-4.346E+00	-1.125E+01	-7.749E+00	1.077E-01	2.503E+0
121	2.622E-03	3.696E+15	-6.937E+00	-7.107E+00	-3.165E+00	1.156E-01	5.374E+0
122	2.678E-04	5.856E+14	-5.892E+00	-8.196E+00	-6.512E+00	1.616E-01	8.480E+0
123	1.648E-05	5.873E+13	-5.175E+00	-8.242E+00	-2.948E+00	1.782E-01	3.448E+0
124	3.960E-06	1.051E+15	-6.539E+00	-6.530E+00	-5.162E+00	1.451E-01	1.011E+0
125	1.181E-04	1.691E+15	-6.009E+00	-8.634E+00	-6.427E+00	1.114E-01	1.021E+0
126	1.359E-01	1.100E+14	-6.347E+00	-8.231E+00	-4.617E+00	1.333E-01	2.839E+0
127	1.662E-04	1.086E+15	-5.805E+00	-7.071E+00	-3.705E+00	1.049E-01	4.405E+0
128	3.621E+01	8.287E+13	-5.634E+00	-8.644E+00	-4.323E+00	1.936E-01	3.909E+0
129	2.476E+00	6.668E+14	-4.958E+00	-7.703E+00	-3.383E+00	8.127E-02	7.248E+0

130	2.797E-01	1.898E+14	-5.334E+00	-7.156E+00	-2.347E+00	1.305E-01	7.195E+0
131	3.857E-03	3.390E+14	-5.951E+00	-1.005E+01	-2.933E+00	1.248E-01	3.138E+0
132	1.123E-06	5.495E+14	-7.788E+00	-8.586E+00	-7.474E+00	2.057E-01	3.917E+0
133	4.041E-03	7.336E+13	-6.295E+00	-7.866E+00	-3.807E+00	9.984E-02	2.859E+0
134	4.518E-04	7.882E+13	-5.606E+00	-7.191E+00	-6.463E+00	1.788E-01	2.760E+0
135	2.324E+02	2.584E+15	-5.461E+00	-6.967E+00	-4.954E+00	2.363E-01	4.971E+0
136	6.516E-02	1.761E+15	-5.848E+00	-7.171E+00	-7.106E+00	1.527E-01	5.926E+0
137	6.115E-05	3.727E+14	-6.477E+00	-1.036E+01	-7.601E+00	1.629E-01	9.646E+0
138	5.404E-02	2.821E+14	-6.287E+00	-6.454E+00	-3.907E+00	1.187E-01	3.246E+0
139	2.162E-06	3.263E+14	-5.548E+00	-7.141E+00	-5.866E+00	1.032E-01	3.194E+0
140	2.174E+00	1.018E+15	-5.580E+00	-9.152E+00	-7.829E+00	6.859E-02	3.320E+0
141	8.076E-03	1.405E+14	-6.212E+00	-7.817E+00	-5.096E+00	1.617E-01	9.206E+0
142	2.875E-05	6.250E+13	-5.769E+00	-8.401E+00	-7.662E+00	2.420E-01	3.088E+0
143	6.666E-05	5.127E+15	-6.427E+00	-8.303E+00	-8.337E+00	1.624E-01	4.746E+0
144	1.613E-05	2.426E+14	-5.150E+00	-7.196E+00	-8.197E+00	1.783E-01	2.712E+0
145	4.040E+02	1.876E+14	-6.265E+00	-5.656E+00	-3.755E+00	1.426E-01	9.083E+0
146	8.087E+02	2.206E+15	-5.924E+00	-8.915E+00	-7.729E+00	1.642E-01	7.432E+0
147	3.706E+02	1.516E+14	-5.015E+00	-7.040E+00	-3.262E+00	1.617E-01	9.494E+0
148	1.067E-02	2.094E+14	-5.265E+00	-9.383E+00	-7.354E+00	1.474E-01	8.581E+0
149	5.337E-04	2.824E+15	-5.535E+00	-8.326E+00	-4.049E+00	1.232E-01	2.648E+0
150	1.616E+01	5.693E+13	-5.982E+00	-8.728E+00	-7.909E+00	1.783E-01	2.772E+0
151	5.974E-06	1.051E+14	-4.871E+00	-6.904E+00	-4.519E+00	9.811E-02	8.670E+0
152	3.179E-01	8.886E+14	-5.203E+00	-8.094E+00	-6.619E+00	1.063E-01	7.890E+0
153	2.917E+00	1.647E+14	-5.713E+00	-1.089E+01	-2.631E+00	1.229E-01	2.383E+0
154	1.793E+02	3.140E+14	-5.052E+00	-7.214E+00	-5.257E+00	1.818E-01	4.139E+0
155	4.599E-04	5.289E+15	-6.100E+00	-1.059E+01	-5.893E+00	1.447E-01	9.581E+0
156	9.606E+00	3.979E+14	-3.042E+00	-7.028E+00	-4.114E+00	2.043E-01	2.329E+0
157	6.904E-06	8.986E+13	-2.454E+00	-8.896E+00	-6.538E+00	1.154E-01	9.933E+0
158	2.138E-02	1.449E+14	-6.239E+00	-8.063E+00	-6.573E+00	1.166E-01	8.317E+0
159	1.511E+00	2.875E+14	-5.197E+00	-8.490E+00	-6.772E+00	1.211E-01	5.247E+0
160	1.128E-02	5.641E+14	-5.156E+00	-8.625E+00	-6.908E+00	2.029E-01	3.867E+0
161	4.517E+02	4.673E+14	-5.407E+00	-5.556E+00	-6.679E+00	1.168E-01	4.256E+0
162	1.673E+02	1.916E+15	-7.003E+00	-8.369E+00	-5.513E+00	1.648E-01	6.795E+0
163	2.244E-03	1.782E+15	-6.799E+00	-7.119E+00	-5.030E+00	1.350E-01	3.602E+0
164	5.448E-01	2.204E+14	-5.364E+00	-8.381E+00	-6.289E+00	1.443E-01	2.449E+0
165	6.373E-04	2.370E+15	-5.699E+00	-6.800E+00	-3.881E+00	1.222E-01	6.705E+0
166	2.050E-05	8.189E+13	-3.244E+00	-7.061E+00	-4.151E+00	2.063E-01	8.435E+0
167	6.714E-02	2.587E+14	-7.363E+00	-1.153E+01	-5.944E+00	1.021E-01	4.570E+0
168	2.207E+01	2.736E+15	-2.185E+00	-8.978E+00	-4.979E+00	1.392E-01	9.505E+0
169	8.257E+02	4.949E+15	-5.065E+00	-7.357E+00	-8.231E+00	1.217E-01	2.910E+0
170	3.735E+00	1.435E+14	-5.731E+00	-7.997E+00	-4.389E+00	1.663E-01	1.019E+0
171	2.886E-06	1.865E+15	-5.662E+00	-7.535E+00	-3.956E+00	1.208E-01	5.664E+0

172	1.819E-03	2.016E+15	-5.676E+00	-7.098E+00	-7.983E+00	1.052E-01	9.098E+0
173	2.350E-05	8.640E+13	-5.935E+00	-8.427E+00	-3.285E+00	1.511E-01	8.074E+0
174	2.740E-06	5.428E+15	-5.616E+00	-8.877E+00	-7.034E+00	1.224E-01	5.863E+0
175	4.575E-03	3.473E+14	-5.353E+00	-8.336E+00	-7.461E+00	1.363E-01	2.790E+0
176	8.124E-02	4.009E+15	-2.669E+00	-8.486E+00	-5.542E+00	9.258E-02	3.468E+0
177	4.838E-06	4.951E+14	-6.384E+00	-5.954E+00	-5.340E+00	1.254E-01	6.279E+0
178	5.649E+00	8.351E+14	-2.836E+00	-8.833E+00	-2.528E+00	1.604E-01	7.513E+0
179	2.299E+00	6.740E+13	-5.960E+00	-5.388E+00	-4.673E+00	1.385E-01	5.735E+0
180	7.365E-01	7.205E+13	-4.993E+00	-6.885E+00	-6.948E+00	1.177E-01	5.537E+0
181	1.744E+00	1.323E+14	-6.311E+00	-8.264E+00	-2.020E+00	1.034E-01	3.692E+0
182	1.388E+02	4.339E+14	-5.569E+00	-7.501E+00	-6.663E+00	1.012E-01	2.683E+0
183	1.399E+00	7.381E+14	-6.344E+00	-1.107E+01	-6.122E+00	1.781E-01	8.761E+0
184	1.512E-06	1.276E+14	-5.797E+00	-8.180E+00	-7.403E+00	1.486E-01	7.991E+0
185	7.985E-05	1.591E+15	-5.279E+00	-7.449E+00	-7.065E+00	1.919E-01	6.181E+0
186	3.004E+02	8.266E+14	-6.492E+00	-6.183E+00	-3.204E+00	1.782E-01	6.320E+0
187	5.752E-06	2.334E+15	-6.684E+00	-6.513E+00	-7.243E+00	1.858E-01	4.065E+0
188	1.880E+00	1.301E+14	-4.757E+00	-6.753E+00	-6.264E+00	1.226E-01	6.544E+0
189	8.359E+00	2.061E+15	-6.520E+00	-8.540E+00	-5.588E+00	1.722E-01	2.611E+0
190	6.238E-01	1.782E+14	-4.567E+00	-6.743E+00	-3.447E+00	1.132E-01	6.928E+0
191	3.942E+01	2.751E+14	-4.926E+00	-8.029E+00	-8.061E+00	1.634E-01	3.586E+0
192	2.001E-02	1.230E+14	-7.469E+00	-8.602E+00	-3.978E+00	1.740E-01	3.996E+0
193	2.649E-03	2.175E+15	-6.414E+00	-5.493E+00	-5.448E+00	1.792E-01	4.048E+0
194	2.582E+01	2.671E+15	-5.436E+00	-8.356E+00	-4.241E+00	1.781E-01	3.964E+0
195	4.558E-02	5.775E+13	-6.393E+00	-9.777E+00	-8.443E+00	1.233E-01	5.719E+0
196	9.421E-04	2.065E+14	-6.406E+00	-8.675E+00	-6.983E+00	1.619E-01	6.245E+0
197	3.364E+00	1.224E+15	-5.330E+00	-7.331E+00	-5.079E+00	2.017E-01	7.718E+0
198	9.142E+00	1.641E+15	-5.276E+00	-7.955E+00	-7.411E+00	1.681E-01	6.367E+0
199	9.915E+01	3.586E+15	-6.069E+00	-7.838E+00	-2.406E+00	1.458E-01	8.897E+0
200	1.018E-04	2.998E+14	-5.044E+00	-6.613E+00	-4.484E+00	1.419E-01	9.820E+0

LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(21)
1	3.400E+01
2	4.000E+01
3	2.300E+01
4	4.000E+01
5	8.000E+00
6	2.300E+01
7	2.300E+01
8	2.300E+01
9	8.000E+00
10	4.000E+01
11	4.000E+01

12 2.300E+01
13 2.300E+01
14 3.400E+01
15 8.000E+00
16 2.300E+01
17 2.300E+01
18 2.300E+01
19 -1.000E+01
20 2.000E+00
21 4.000E+01
22 8.000E+00
23 4.000E+01
24 2.000E+00
25 8.000E+00
26 2.000E+00
27 3.400E+01
28 4.000E+01
29 -1.000E+01
30 4.000E+01
31 3.400E+01
32 2.300E+01
33 3.400E+01
34 8.000E+00
35 4.000E+01
36 8.000E+00
37 4.000E+01
38 -1.000E+01
39 8.000E+00
40 4.000E+01
41 3.400E+01
42 8.000E+00
43 3.400E+01
44 2.300E+01
45 2.300E+01
46 2.000E+00
47 2.000E+00
48 8.000E+00
49 8.000E+00
50 8.000E+00
51 2.300E+01
52 4.000E+01
53 8.000E+00

54 2.000E+00
55 3.400E+01
56 8.000E+00
57 2.300E+01
58 -1.000E+01
59 8.000E+00
60 3.400E+01
61 8.000E+00
62 2.000E+00
63 -1.000E+01
64 8.000E+00
65 8.000E+00
66 4.000E+01
67 8.000E+00
68 2.000E+00
69 2.000E+00
70 -1.000E+01
71 8.000E+00
72 -1.000E+01
73 8.000E+00
74 8.000E+00
75 2.300E+01
76 -1.000E+01
77 2.000E+00
78 4.000E+01
79 8.000E+00
80 3.400E+01
81 -1.000E+01
82 -1.000E+01
83 2.000E+00
84 -1.000E+01
85 4.000E+01
86 3.400E+01
87 8.000E+00
88 3.400E+01
89 8.000E+00
90 2.300E+01
91 8.000E+00
92 2.300E+01
93 2.000E+00
94 4.000E+01
95 -1.000E+01

96 2.300E+01
97 2.000E+00
98 3.400E+01
99 3.400E+01
100 8.000E+00
101 4.000E+01
102 4.000E+01
103 3.400E+01
104 2.000E+00
105 8.000E+00
106 8.000E+00
107 4.000E+01
108 -1.000E+01
109 2.300E+01
110 4.000E+01
111 8.000E+00
112 2.300E+01
113 8.000E+00
114 4.000E+01
115 -1.000E+01
116 3.400E+01
117 8.000E+00
118 2.000E+00
119 -1.000E+01
120 -1.000E+01
121 8.000E+00
122 2.000E+00
123 3.400E+01
124 4.000E+01
125 4.000E+01
126 2.300E+01
127 2.300E+01
128 2.000E+00
129 3.400E+01
130 2.000E+00
131 4.000E+01
132 3.400E+01
133 2.000E+00
134 4.000E+01
135 2.300E+01
136 8.000E+00
137 4.000E+01

138 -1.000E+01
139 -1.000E+01
140 3.400E+01
141 -1.000E+01
142 2.300E+01
143 4.000E+01
144 8.000E+00
145 3.400E+01
146 2.300E+01
147 8.000E+00
148 8.000E+00
149 2.300E+01
150 8.000E+00
151 8.000E+00
152 4.000E+01
153 3.400E+01
154 3.400E+01
155 -1.000E+01
156 -1.000E+01
157 8.000E+00
158 8.000E+00
159 8.000E+00
160 4.000E+01
161 4.000E+01
162 8.000E+00
163 8.000E+00
164 2.000E+00
165 3.400E+01
166 2.000E+00
167 2.000E+00
168 2.300E+01
169 3.400E+01
170 2.000E+00
171 4.000E+01
172 3.400E+01
173 2.300E+01
174 2.000E+00
175 8.000E+00
176 3.400E+01
177 4.000E+01
178 2.000E+00
179 -1.000E+01

180 -1.000E+01
 181 3.400E+01
 182 8.000E+00
 183 4.000E+01
 184 2.300E+01
 185 -1.000E+01
 186 8.000E+00
 187 2.000E+00
 188 4.000E+01
 189 8.000E+00
 190 2.300E+01
 191 4.000E+01
 192 3.400E+01
 193 3.400E+01
 194 8.000E+00
 195 4.000E+01
 196 -1.000E+01
 197 -1.000E+01
 198 8.000E+00
 199 8.000E+00
 200 8.000E+00

RANKS OF LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(1)	X(2)	X(3)	X(4)	X(5)	X(6)	X(7)
1	142.	200.	2.	75.	79.	114.	86
2	38.	15.	135.	19.	124.	26.	55
3	31.	168.	82.	113.	41.	32.	135
4	75.	63.	7.	141.	100.	11.	27
5	120.	38.	121.	147.	141.	158.	190
6	80.	25.	108.	11.	88.	2.	101
7	66.	55.	100.	35.	3.	150.	146
8	190.	73.	193.	122.	46.	160.	14
9	157.	181.	200.	142.	164.	67.	139
10	81.	33.	122.	129.	142.	198.	89
11	26.	198.	5.	146.	190.	181.	109
12	171.	82.	141.	67.	25.	175.	92
13	74.	149.	94.	21.	167.	33.	200
14	156.	131.	128.	134.	119.	174.	182
15	48.	71.	124.	68.	56.	83.	115
16	94.	56.	67.	27.	125.	57.	28
17	50.	65.	111.	97.	130.	73.	38
18	136.	100.	200.	77.	53.	53.	17
19	59.	43.	84.	83.	26.	110.	31

20	84.	36.	99.	53.	158.	87.	70
21	127.	46.	29.	110.	153.	102.	26
22	67.	200.	123.	25.	160.	31.	51
23	58.	116.	177.	24.	14.	182.	108
24	128.	53.	51.	43.	177.	126.	15
25	155.	196.	181.	48.	4.	46.	107
26	4.	175.	126.	178.	47.	8.	176
27	6.	98.	120.	12.	107.	19.	138
28	154.	28.	148.	51.	36.	108.	104
29	110.	145.	182.	80.	97.	10.	152
30	123.	77.	76.	200.	2.	27.	158
31	2.	119.	116.	54.	102.	92.	96
32	95.	160.	163.	117.	174.	72.	178
33	185.	3.	149.	194.	22.	56.	9
34	105.	172.	47.	154.	151.	192.	21
35	188.	157.	78.	195.	71.	159.	105
36	121.	111.	178.	32.	113.	113.	196
37	42.	136.	174.	184.	165.	13.	160
38	144.	195.	189.	140.	72.	6.	42
39	5.	96.	35.	185.	50.	70.	165
40	108.	78.	90.	91.	145.	43.	149
41	152.	7.	131.	135.	90.	104.	97
42	13.	80.	6.	55.	195.	112.	162
43	96.	88.	18.	40.	200.	128.	32
44	112.	6.	13.	172.	146.	48.	116
45	102.	44.	114.	59.	9.	152.	142
46	192.	66.	44.	151.	42.	77.	125
47	62.	64.	134.	44.	20.	166.	13
48	109.	171.	91.	13.	44.	64.	122
49	124.	133.	79.	162.	132.	137.	185
50	172.	146.	155.	17.	183.	96.	161
51	70.	94.	98.	124.	76.	145.	102
52	23.	67.	11.	179.	128.	29.	56
53	43.	110.	50.	82.	58.	140.	63
54	93.	18.	41.	183.	8.	164.	121
55	177.	23.	101.	79.	197.	103.	8
56	85.	187.	129.	64.	17.	42.	33
57	64.	21.	46.	66.	85.	124.	103
58	193.	125.	105.	88.	166.	170.	111
59	34.	124.	197.	173.	181.	163.	195
60	71.	117.	32.	5.	60.	153.	74
61	116.	128.	144.	169.	111.	79.	64

62	200.	35.	33.	6.	163.	141.	113
63	9.	48.	179.	72.	149.	15.	131
64	24.	156.	145.	36.	121.	88.	166
65	7.	167.	169.	18.	176.	161.	134
66	40.	147.	175.	188.	80.	74.	58
67	44.	87.	4.	4.	117.	122.	34
68	68.	17.	191.	89.	31.	136.	30
69	122.	47.	139.	197.	49.	54.	187
70	55.	108.	166.	106.	189.	100.	76
71	139.	10.	49.	61.	116.	90.	118
72	178.	9.	150.	3.	96.	109.	129
73	170.	2.	71.	99.	92.	81.	143
74	99.	13.	151.	74.	75.	5.	177
75	194.	188.	125.	193.	62.	95.	173
76	113.	24.	173.	15.	168.	148.	11
77	57.	30.	88.	16.	118.	58.	54
78	111.	97.	74.	86.	123.	60.	25
79	53.	86.	104.	138.	185.	200.	62
80	30.	95.	142.	191.	68.	35.	123
81	143.	90.	107.	164.	138.	146.	169
82	86.	194.	95.	41.	51.	22.	72
83	46.	182.	17.	126.	83.	134.	156
84	22.	51.	2.	119.	93.	3.	18
85	175.	129.	57.	182.	104.	9.	94
86	36.	154.	158.	112.	103.	39.	3
87	15.	185.	133.	136.	171.	154.	65
88	189.	42.	9.	163.	81.	185.	52
89	148.	130.	117.	62.	182.	168.	91
90	107.	37.	81.	65.	188.	7.	20
91	88.	31.	156.	22.	11.	135.	83
92	141.	158.	140.	76.	13.	131.	154
93	160.	121.	72.	108.	196.	156.	150
94	2.	75.	113.	155.	87.	51.	120
95	14.	54.	70.	131.	65.	129.	88
96	37.	161.	53.	20.	16.	165.	2
97	54.	5.	66.	176.	110.	82.	24
98	32.	26.	39.	181.	200.	44.	130
99	140.	148.	63.	2.	98.	93.	98
100	153.	102.	172.	192.	74.	65.	144
101	65.	178.	194.	161.	55.	120.	112
102	76.	74.	31.	38.	161.	12.	168
103	176.	180.	159.	81.	114.	36.	12

104	56.	135.	136.	95.	12.	200.	133
105	117.	109.	127.	58.	187.	61.	50
106	60.	39.	119.	132.	7.	116.	147
107	87.	62.	154.	14.	122.	28.	197
108	161.	11.	27.	107.	6.	121.	141
109	186.	183.	25.	94.	38.	193.	198
110	131.	112.	86.	84.	52.	119.	16
111	51.	61.	87.	90.	131.	76.	82
112	119.	91.	83.	152.	82.	45.	172
113	73.	79.	170.	189.	144.	123.	22
114	115.	76.	196.	7.	23.	186.	57
115	52.	197.	165.	153.	15.	55.	192
116	8.	126.	60.	96.	45.	195.	66
117	69.	69.	171.	56.	143.	177.	44
118	184.	58.	167.	118.	126.	66.	151
119	10.	45.	20.	167.	78.	191.	170
120	135.	138.	64.	70.	115.	91.	68
121	146.	114.	21.	63.	152.	173.	191
122	89.	118.	62.	159.	147.	179.	4
123	77.	29.	14.	115.	193.	147.	179
124	159.	123.	137.	160.	106.	16.	87
125	25.	4.	176.	26.	175.	162.	46
126	181.	137.	10.	46.	136.	151.	180
127	61.	153.	89.	198.	129.	183.	7
128	158.	170.	102.	156.	173.	38.	75
129	92.	70.	143.	98.	33.	80.	99
130	33.	140.	184.	100.	66.	107.	194
131	47.	83.	157.	123.	162.	125.	189
132	21.	166.	93.	103.	21.	24.	36
133	16.	184.	190.	165.	40.	178.	5
134	168.	186.	16.	133.	48.	18.	35
135	169.	89.	37.	31.	2.	184.	29
136	79.	163.	3.	28.	5.	157.	175
137	126.	173.	65.	109.	89.	196.	183
138	163.	101.	43.	128.	84.	30.	171
139	167.	92.	24.	187.	69.	85.	155
140	11.	155.	198.	137.	194.	180.	148
141	98.	134.	52.	168.	154.	143.	67
142	198.	164.	40.	127.	120.	20.	77
143	49.	32.	96.	171.	105.	127.	100
144	100.	169.	26.	186.	172.	117.	1
145	97.	41.	106.	73.	184.	50.	117

146	150.	193.	97.	85.	192.	25.	47
147	82.	151.	30.	49.	169.	71.	10
148	17.	122.	12.	78.	39.	86.	124
149	90.	104.	168.	39.	54.	149.	167
150	162.	84.	164.	93.	61.	59.	110
151	164.	52.	45.	114.	67.	115.	145
152	147.	16.	36.	139.	29.	176.	59
153	28.	176.	160.	101.	37.	106.	114
154	18.	103.	15.	42.	94.	34.	126
155	106.	107.	186.	150.	134.	68.	45
156	145.	174.	92.	190.	99.	142.	136
157	101.	141.	38.	29.	108.	155.	61
158	165.	113.	185.	121.	186.	169.	19
159	118.	152.	77.	2.	133.	190.	174
160	20.	50.	187.	102.	109.	197.	85
161	35.	191.	54.	148.	43.	4.	79
162	173.	192.	8.	170.	86.	138.	48
163	12.	150.	80.	30.	155.	132.	163
164	182.	34.	103.	200.	179.	139.	41
165	200.	144.	28.	47.	30.	188.	37
166	63.	49.	132.	105.	24.	94.	53
167	19.	105.	22.	87.	32.	111.	95
168	125.	85.	61.	180.	180.	189.	199
169	149.	68.	195.	166.	178.	118.	49
170	41.	142.	69.	111.	18.	167.	73
171	179.	190.	109.	34.	63.	130.	60
172	104.	179.	58.	8.	70.	40.	90
173	197.	159.	192.	50.	148.	52.	6
174	103.	162.	19.	143.	150.	17.	119
175	45.	143.	34.	52.	95.	14.	43
176	195.	40.	68.	120.	34.	23.	93
177	129.	115.	75.	196.	91.	89.	188
178	137.	19.	85.	92.	140.	37.	71
179	91.	120.	130.	157.	139.	194.	159
180	191.	72.	153.	9.	28.	21.	69
181	132.	59.	147.	45.	101.	144.	128
182	27.	81.	23.	130.	59.	75.	84
183	180.	20.	48.	116.	64.	2.	193
184	196.	106.	180.	144.	137.	172.	80
185	183.	99.	56.	145.	112.	41.	127
186	166.	177.	42.	57.	73.	97.	81
187	39.	57.	59.	104.	191.	171.	106

188	134.	8.	188.	23.	77.	47.	153
189	29.	12.	138.	149.	19.	98.	140
190	83.	127.	161.	33.	127.	105.	181
191	130.	14.	55.	69.	156.	69.	184
192	151.	93.	183.	158.	27.	101.	78
193	3.	2.	146.	175.	157.	99.	23
194	114.	132.	162.	174.	135.	133.	39
195	72.	22.	115.	71.	35.	187.	157
196	187.	60.	152.	37.	198.	78.	186
197	78.	27.	73.	177.	10.	49.	164
198	174.	139.	118.	60.	159.	63.	132
199	133.	165.	110.	125.	57.	62.	40
200	138.	189.	112.	10.	170.	84.	137

RANKS OF LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(11)	X(12)	X(13)	X(14)	X(15)	X(16)	X(17)
1	102.	137.	91.	100.	11.	4.	109
2	46.	143.	120.	183.	50.	129.	176
3	105.	76.	66.	109.	88.	23.	79
4	130.	132.	38.	42.	120.	145.	134
5	101.	133.	195.	103.	83.	190.	102
6	163.	46.	157.	21.	7.	97.	37
7	124.	82.	186.	175.	93.	37.	123
8	71.	155.	188.	173.	130.	71.	192
9	74.	111.	84.	168.	177.	178.	2
10	134.	152.	138.	164.	149.	166.	7
11	159.	177.	174.	71.	131.	103.	158
12	25.	33.	54.	132.	43.	172.	25
13	5.	109.	12.	101.	184.	72.	141
14	174.	56.	20.	152.	171.	81.	118
15	38.	87.	162.	178.	75.	39.	162
16	185.	84.	175.	108.	86.	152.	22
17	153.	130.	4.	127.	126.	51.	138
18	187.	200.	2.	4.	160.	185.	101
19	190.	8.	177.	99.	87.	133.	190
20	182.	91.	86.	5.	117.	151.	46
21	195.	24.	5.	113.	191.	77.	112
22	173.	52.	21.	199.	94.	48.	33
23	13.	114.	58.	92.	27.	75.	84
24	35.	23.	141.	110.	124.	80.	97
25	51.	187.	173.	119.	28.	182.	87
26	58.	184.	49.	190.	47.	11.	180
27	78.	96.	189.	94.	16.	200.	114

28	23.	103.	68.	133.	48.	193.	182
29	117.	165.	51.	56.	164.	192.	195
30	111.	172.	24.	1.	128.	30.	161
31	188.	49.	79.	159.	161.	119.	3
32	145.	16.	64.	77.	140.	191.	58
33	68.	69.	179.	80.	60.	1.	108
34	158.	10.	72.	91.	49.	196.	199
35	32.	106.	180.	78.	98.	105.	166
36	177.	78.	171.	89.	153.	169.	137
37	132.	7.	43.	12.	3.	64.	149
38	152.	125.	148.	130.	4.	33.	183
39	34.	39.	191.	122.	189.	34.	32
40	197.	105.	165.	86.	82.	84.	173
41	85.	31.	90.	58.	198.	15.	151
42	12.	173.	166.	98.	33.	32.	85
43	79.	164.	107.	30.	170.	35.	10
44	125.	115.	126.	150.	193.	56.	88
45	120.	136.	178.	196.	175.	144.	75
46	170.	110.	87.	114.	64.	170.	60
47	121.	34.	31.	172.	58.	183.	99
48	20.	90.	113.	163.	100.	12.	28
49	200.	59.	28.	176.	8.	78.	157
50	116.	140.	127.	112.	148.	127.	155
51	7.	119.	176.	157.	44.	26.	30
52	179.	122.	59.	131.	99.	110.	117
53	92.	188.	11.	105.	45.	175.	27
54	62.	178.	7.	111.	61.	6.	52
55	9.	142.	187.	124.	178.	79.	94
56	64.	65.	94.	125.	108.	165.	92
57	88.	113.	82.	84.	169.	126.	171
58	118.	139.	71.	39.	129.	59.	184
59	57.	29.	149.	187.	23.	100.	146
60	114.	25.	80.	75.	17.	9.	62
61	15.	174.	96.	19.	143.	161.	170
62	136.	149.	118.	169.	107.	17.	43
63	42.	179.	39.	170.	197.	136.	128
64	89.	192.	123.	7.	77.	99.	71
65	109.	170.	200.	107.	1.	163.	53
66	160.	193.	160.	2.	105.	55.	57
67	53.	66.	53.	36.	76.	106.	63
68	52.	141.	61.	123.	10.	46.	89
69	29.	166.	169.	66.	115.	194.	8

70	56.	22.	144.	29.	183.	13.	45
71	55.	98.	151.	106.	81.	168.	11
72	98.	190.	83.	35.	96.	93.	35
73	24.	45.	32.	121.	125.	150.	18
74	194.	131.	168.	48.	89.	27.	103
75	72.	48.	93.	189.	31.	94.	5
76	69.	158.	125.	96.	25.	121.	115
77	133.	26.	1.	197.	5.	2.	40
78	66.	191.	117.	182.	68.	148.	105
79	44.	196.	103.	200.	12.	160.	47
80	37.	68.	198.	154.	101.	40.	177
81	171.	123.	22.	191.	36.	95.	156
82	3.	88.	67.	3.	173.	22.	61
83	26.	180.	133.	82.	199.	156.	165
84	113.	138.	116.	167.	145.	195.	168
85	21.	99.	185.	116.	37.	116.	132
86	149.	4.	115.	25.	167.	58.	81
87	180.	27.	183.	33.	80.	61.	29
88	94.	74.	56.	102.	152.	113.	48
89	166.	20.	57.	160.	22.	149.	145
90	6.	32.	42.	87.	137.	140.	189
91	167.	116.	30.	149.	196.	50.	127
92	135.	107.	69.	23.	111.	83.	14
93	175.	161.	60.	74.	97.	65.	77
94	39.	6.	99.	134.	63.	179.	148
95	83.	104.	47.	67.	136.	108.	93
96	162.	189.	158.	177.	188.	53.	64
97	49.	62.	55.	24.	19.	124.	65
98	172.	194.	26.	40.	135.	76.	82
99	126.	176.	150.	49.	168.	162.	38
100	148.	124.	16.	55.	20.	8.	119
101	100.	120.	132.	171.	172.	142.	130
102	22.	50.	18.	37.	109.	130.	96
103	127.	175.	163.	90.	141.	29.	136
104	70.	185.	153.	17.	95.	109.	31
105	36.	183.	102.	198.	54.	49.	54
106	150.	135.	114.	129.	59.	118.	110
107	84.	145.	13.	186.	85.	86.	91
108	196.	144.	140.	76.	2.	89.	174
109	99.	97.	10.	34.	15.	189.	159
110	48.	63.	152.	148.	146.	137.	12
111	1.	81.	139.	52.	112.	186.	74

112	119.	127.	190.	158.	187.	199.	42
113	157.	43.	63.	184.	35.	128.	142
114	93.	94.	6.	51.	166.	174.	121
115	65.	13.	134.	118.	132.	91.	116
116	176.	61.	170.	32.	127.	117.	194
117	103.	14.	110.	14.	114.	70.	153
118	95.	85.	74.	161.	74.	5.	49
119	86.	55.	122.	153.	155.	67.	200
120	112.	92.	184.	8.	29.	31.	9
121	76.	182.	15.	142.	182.	42.	98
122	54.	102.	81.	72.	71.	122.	164
123	28.	3.	145.	69.	185.	155.	50
124	14.	128.	23.	179.	116.	104.	196
125	47.	148.	70.	44.	73.	36.	198
126	115.	30.	40.	70.	134.	85.	23
127	50.	129.	88.	144.	165.	24.	80
128	168.	18.	104.	43.	144.	177.	67
129	143.	108.	164.	104.	176.	7.	140
130	122.	54.	130.	139.	195.	82.	139
131	80.	79.	76.	15.	186.	73.	36
132	2.	100.	3.	47.	38.	187.	68
133	81.	12.	45.	93.	162.	16.	24
134	59.	15.	106.	137.	72.	164.	19
135	186.	167.	119.	151.	123.	197.	90
136	107.	150.	85.	138.	51.	115.	113
137	40.	83.	29.	13.	34.	134.	188
138	106.	71.	46.	181.	158.	47.	41
139	8.	77.	111.	140.	92.	20.	39
140	141.	126.	108.	20.	26.	3.	44
141	87.	40.	52.	97.	118.	125.	181
142	33.	5.	92.	59.	32.	198.	34
143	41.	197.	33.	65.	9.	132.	86
144	27.	64.	147.	136.	14.	159.	17
145	192.	53.	48.	192.	163.	98.	178
146	198.	160.	78.	26.	30.	138.	143
147	191.	44.	159.	146.	180.	123.	185
148	90.	58.	137.	18.	42.	111.	167
149	61.	171.	112.	64.	154.	68.	15
150	161.	1.	73.	38.	24.	158.	20
151	18.	28.	172.	155.	138.	14.	169
152	123.	121.	142.	79.	67.	28.	150
153	144.	47.	97.	10.	190.	66.	4

154	184.	75.	155.	135.	113.	171.	76
155	60.	198.	62.	11.	91.	102.	187
156	156.	86.	193.	147.	151.	184.	1
157	19.	21.	197.	27.	70.	41.	193
158	97.	42.	50.	81.	69.	43.	160
159	138.	72.	143.	53.	62.	54.	95
160	91.	101.	146.	45.	57.	181.	66
161	193.	93.	124.	193.	65.	44.	78
162	183.	154.	14.	61.	104.	139.	133
163	75.	151.	17.	141.	121.	87.	56
164	128.	60.	128.	60.	78.	101.	6
165	63.	163.	98.	162.	159.	60.	131
166	30.	17.	192.	145.	150.	188.	163
167	108.	67.	9.	6.	90.	19.	83
168	164.	169.	199.	22.	122.	92.	186
169	199.	195.	154.	126.	13.	57.	26
170	147.	41.	95.	85.	142.	141.	197
171	11.	153.	101.	115.	157.	52.	104
172	73.	156.	100.	143.	21.	25.	179
173	31.	19.	77.	57.	179.	114.	154
174	10.	199.	105.	28.	53.	62.	111
175	82.	80.	129.	63.	39.	88.	21
176	110.	186.	196.	54.	103.	10.	51
177	16.	95.	37.	188.	110.	74.	124
178	151.	118.	194.	31.	192.	120.	144
179	142.	9.	75.	195.	133.	90.	107
180	131.	11.	161.	156.	56.	45.	100
181	139.	38.	44.	68.	200.	21.	59
182	181.	89.	109.	117.	66.	18.	16
183	137.	112.	41.	9.	84.	154.	172
184	4.	36.	89.	73.	41.	112.	152
185	43.	146.	135.	120.	52.	176.	120
186	189.	117.	27.	185.	181.	157.	125
187	17.	162.	19.	180.	46.	173.	73
188	140.	37.	181.	165.	79.	63.	129
189	154.	157.	25.	50.	102.	146.	13
190	129.	51.	182.	166.	174.	38.	135
191	169.	70.	167.	83.	18.	135.	55
192	96.	35.	8.	46.	156.	147.	70
193	77.	159.	34.	194.	106.	167.	72
194	165.	168.	121.	62.	147.	153.	69
195	104.	2.	36.	16.	6.	69.	106

196	67.	57.	35.	41.	55.	131.	122
197	146.	134.	131.	128.	119.	180.	147
198	155.	147.	136.	88.	40.	143.	126
199	178.	181.	65.	95.	194.	107.	175
200	45.	73.	156.	174.	139.	96.	191

RANKS OF LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(21)
1	150.
2	183.
3	120.
4	183.
5	79.
6	120.
7	120.
8	120.
9	79.
10	183.
11	183.
12	120.
13	120.
14	150.
15	79.
16	120.
17	120.
18	120.
19	14.
20	40.
21	183.
22	79.
23	183.
24	40.
25	79.
26	40.
27	150.
28	183.
29	14.
30	183.
31	150.
32	120.
33	150.
34	79.
35	183.

36	79.
37	183.
38	14.
39	79.
40	183.
41	150.
42	79.
43	150.
44	120.
45	120.
46	40.
47	40.
48	79.
49	79.
50	79.
51	120.
52	183.
53	79.
54	40.
55	150.
56	79.
57	120.
58	14.
59	79.
60	150.
61	79.
62	40.
63	14.
64	79.
65	79.
66	183.
67	79.
68	40.
69	40.
70	14.
71	79.
72	14.
73	79.
74	79.
75	120.
76	14.
77	40.

78	183.
79	79.
80	150.
81	14.
82	14.
83	40.
84	14.
85	183.
86	150.
87	79.
88	150.
89	79.
90	120.
91	79.
92	120.
93	40.
94	183.
95	14.
96	120.
97	40.
98	150.
99	150.
100	79.
101	183.
102	183.
103	150.
104	40.
105	79.
106	79.
107	183.
108	14.
109	120.
110	183.
111	79.
112	120.
113	79.
114	183.
115	14.
116	150.
117	79.
118	40.
119	14.

120	14.
121	79.
122	40.
123	150.
124	183.
125	183.
126	120.
127	120.
128	40.
129	150.
130	40.
131	183.
132	150.
133	40.
134	183.
135	120.
136	79.
137	183.
138	14.
139	14.
140	150.
141	14.
142	120.
143	183.
144	79.
145	150.
146	120.
147	79.
148	79.
149	120.
150	79.
151	79.
152	183.
153	150.
154	150.
155	14.
156	14.
157	79.
158	79.
159	79.
160	183.
161	183.

162	79.
163	79.
164	40.
165	150.
166	40.
167	40.
168	120.
169	150.
170	40.
171	183.
172	150.
173	120.
174	40.
175	79.
176	150.
177	183.
178	40.
179	14.
180	14.
181	150.
182	79.
183	183.
184	120.
185	14.
186	79.
187	40.
188	183.
189	79.
190	120.
191	183.
192	150.
193	150.
194	79.
195	183.
196	14.
197	14.
198	79.
199	79.
200	79.

HISTOGRAM FOR VARIABLE NO. 1 NORMAL DISTRIBUTION
MIDPOINT FREQ.

-0.5000000E-02	2	XX
0.5000000E-02	2	XX
0.1500000E-01	2	XX
0.2500000E-01	4	XXXX
0.3500000E-01	6	XXXXXX
0.4500000E-01	9	XXXXXXXXXX
0.5500000E-01	10	XXXXXXXXXXXX
0.6500001E-01	14	XXXXXXXXXXXXXXXXXX
0.7500000E-01	15	XXXXXXXXXXXXXXXXXXXX
0.8500000E-01	17	XXXXXXXXXXXXXXXXXXXXXX
0.9500000E-01	19	XXXXXXXXXXXXXXXXXXXXXXXXXX
0.1050000	18	XXXXXXXXXXXXXXXXXXXXXXXXXX
0.1150000	18	XXXXXXXXXXXXXXXXXXXXXXXXXX
0.1250000	16	XXXXXXXXXXXXXXXXXXXXXX
0.1350000	12	XXXXXXXXXXXXXXXXXX
0.1450000	11	XXXXXXXXXXXXXX
0.1550000	9	XXXXXXXXXXXX
0.1650000	6	XXXXXX
0.1750000	4	XXXX
0.1850000	2	XX
0.1950000	4	XXXX

200

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-0.2235174E-07	0.2000000	0.2000001	0.1000049	0.9989989E-01	0.17

HISTOGRAM FOR VARIABLE NO. 2 NORMAL DISTRIBUTION

MIDPOINT	FREQ.	
586.5001	3	XXX
609.5001	3	XXX
632.5001	4	XXXX
655.5001	5	XXXXX
678.5001	8	XXXXXXXX
701.5001	10	XXXXXXXXXX
724.5001	14	XXXXXXXXXXXXXXXXXX
747.5001	15	XXXXXXXXXXXXXXXXXXXX
770.5001	16	XXXXXXXXXXXXXXXXXXXXXX
793.5001	18	XXXXXXXXXXXXXXXXXXXXXX
816.5001	18	XXXXXXXXXXXXXXXXXXXXXX
839.5001	18	XXXXXXXXXXXXXXXXXXXXXX
862.5001	17	XXXXXXXXXXXXXXXXXXXXXX
885.5001	13	XXXXXXXXXXXXXXXXXX
908.5001	11	XXXXXXXXXXXXXX

-0.1250000	10	XXXXXXXXXX
-0.7499999E-01	10	XXXXXXXXXX
-0.2500001E-01	10	XXXXXXXXXX
0.2499998E-01	10	XXXXXXXXXX
0.7499996E-01	10	XXXXXXXXXX
0.1249999	10	XXXXXXXXXX
0.1749999	10	XXXXXXXXXX
0.2249999	10	XXXXXXXXXX
0.2749999	10	XXXXXXXXXX
0.3249999	10	XXXXXXXXXX
0.3749999	10	XXXXXXXXXX
0.4249998	10	XXXXXXXXXX
0.4749998	10	XXXXXXXXXX

200

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-0.4974287	0.4976968	0.9951255	-0.8040815E-05	0.1142050E-02	0.83

HISTOGRAM FOR VARIABLE NO. 8 UNIFORM DISTRIBUTION

MIDPOINT	FREQ.	
0.2499999E-01	10	XXXXXXXXXX
0.7499997E-01	10	XXXXXXXXXX
0.1250000	10	XXXXXXXXXX
0.1749999	10	XXXXXXXXXX
0.2249999	10	XXXXXXXXXX
0.2749999	10	XXXXXXXXXX
0.3249999	10	XXXXXXXXXX
0.3749999	10	XXXXXXXXXX
0.4249999	10	XXXXXXXXXX
0.4749998	10	XXXXXXXXXX
0.5249999	10	XXXXXXXXXX
0.5749999	10	XXXXXXXXXX
0.6249999	10	XXXXXXXXXX
0.6749999	10	XXXXXXXXXX
0.7249999	10	XXXXXXXXXX
0.7749999	10	XXXXXXXXXX
0.8249999	10	XXXXXXXXXX
0.8749999	10	XXXXXXXXXX
0.9250000	10	XXXXXXXXXX
0.9750000	10	XXXXXXXXXX

200

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.3748673E-02	0.9988270	0.9950784	0.5002130	0.4996909	0.83

0.7000001E+15	18	XXXXXXXXXXXXXXXXXXXX
0.9800001E+15	12	XXXXXXXXXXXX
0.1260000E+16	9	XXXXXXXXXX
0.1540000E+16	8	XXXXXXXXXX
0.1820000E+16	7	XXXXXXX
0.2100000E+16	6	XXXXXX
0.2380000E+16	5	XXXXX
0.2660000E+16	5	XXXXX
0.2940000E+16	4	XXXX
0.3220000E+16	4	XXXX
0.3500000E+16	3	XXX
0.3780000E+16	3	XXX
0.4060000E+16	4	XXXX
0.4340000E+16	3	XXX
0.4620000E+16	2	XX
0.4900000E+16	3	XXX
0.5180000E+16	2	XX
0.5460000E+16	2	XX

200

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.5693017E+14	0.5568388E+16	0.5511457E+16	0.1205019E+16	0.5567769E+15	0.19

HISTOGRAM FOR VARIABLE NO. 13 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
-7.975001	2	XX
-7.685001	5	XXXXX
-7.395001	4	XXXX
-7.105001	3	XXX
-6.815001	5	XXXXX
-6.525001	18	XXXXXXXXXXXXXXXXXXXX
-6.235001	25	XXXXXXXXXXXXXXXXXXXX
-5.945001	26	XXXXXXXXXXXXXXXXXXXX
-5.655001	26	XXXXXXXXXXXXXXXXXXXX
-5.365001	26	XXXXXXXXXXXXXXXXXXXX
-5.075001	25	XXXXXXXXXXXXXXXXXXXX
-4.785001	16	XXXXXXXXXXXXXXXXXXXX
-4.495001	2	XX
-4.205001	2	XX
-3.915001	2	XX
-3.625001	3	XXX
-3.335001	2	XX
-3.045002	1	X

-2.755002	3	XXX
-2.465002	2	XX
-2.175002	2	XX

200

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-7.944694	-2.086470	5.858224	-5.603156	-5.668708	1.0

HISTOGRAM FOR VARIABLE NO. 14 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
-12.42000	1	X
-12.06000	3	XXX
-11.70000	2	XX
-11.34000	2	XX
-10.98000	2	XX
-10.62000	1	X
-10.26000	3	XXX
-9.900001	2	XX
-9.540001	2	XX
-9.180001	2	XX
-8.820002	23	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
-8.460002	23	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
-8.100002	23	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
-7.740002	23	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
-7.380002	23	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
-7.020002	23	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
-6.660002	22	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
-6.300002	5	XXXXX
-5.940001	5	XXXXX
-5.580001	4	XXXX
-5.220001	6	XXXXXX

200

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-12.33655	-5.061714	7.274833	-7.853998	-7.751132	1.8

HISTOGRAM FOR VARIABLE NO. 15 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
-8.745000	1	X
-8.415000	11	XXXXXXXXXXXX
-8.085000	11	XXXXXXXXXXXX
-7.755000	11	XXXXXXXXXXXX
-7.425000	11	XXXXXXXXXXXX
-7.095000	11	XXXXXXXXXXXX

-6.765000	11	XXXXXXXXXXXX
-6.435000	11	XXXXXXXXXXXX
-6.105000	12	XXXXXXXXXXXX
-5.775001	10	XXXXXXXXXXXX
-5.445001	11	XXXXXXXXXXXX
-5.115001	12	XXXXXXXXXXXX
-4.785001	10	XXXXXXXXXXXX
-4.455001	12	XXXXXXXXXXXX
-4.125001	11	XXXXXXXXXXXX
-3.795001	11	XXXXXXXXXXXX
-3.465001	11	XXXXXXXXXXXX
-3.135001	6	XXXXXX
-2.805001	5	XXXXX
-2.475001	6	XXXXXX
-2.145001	5	XXXXX

200

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-8.597218	-2.020330	6.576888	-5.593116	-5.628187	3.1

HISTOGRAM FOR VARIABLE NO. 16 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
0.6174996E-01	2	XX
0.7124996E-01	2	XX
0.8074996E-01	3	XXX
0.9024996E-01	3	XXX
0.9974995E-01	13	XXXXXXXXXXXX
0.1092499	15	XXXXXXXXXXXXXXXX
0.1187499	32	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.1282499	14	XXXXXXXXXXXXXXXX
0.1377499	13	XXXXXXXXXXXXXXXX
0.1472499	17	XXXXXXXXXXXXXXXXXXXX
0.1567499	6	XXXXXX
0.1662499	24	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.1757499	26	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.1852499	5	XXXXXX
0.1947499	4	XXXX
0.2042499	11	XXXXXXXXXXXX
0.2137499	2	XX
0.2232499	3	XXX
0.2327499	2	XX
0.2422499	1	X
0.2517499	2	XX

200

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.6133423E-01	0.2512744	0.1899402	0.1467998	0.1440876	0.14

HISTOGRAM FOR VARIABLE NO. 17 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
22.00000	4	XXXX
26.00000	17	XXXXXXXXXXXXXXXXXXXX
30.00000	18	XXXXXXXXXXXXXXXXXXXX
34.00000	16	XXXXXXXXXXXXXXXXXXXX
38.00000	15	XXXXXXXXXXXXXXXXXXXX
42.00000	9	XXXXXXXXXX
46.00000	8	XXXXXXXXXX
50.00000	7	XXXXXXXXXX
54.00000	8	XXXXXXXXXX
58.00000	13	XXXXXXXXXXXXXXXXXXXX
62.00000	11	XXXXXXXXXXXXXXXXXXXX
65.99999	7	XXXXXXXXXX
69.99999	6	XXXXXXX
73.99999	6	XXXXXXX
77.99999	7	XXXXXXXXXX
81.99999	10	XXXXXXXXXXXX
85.99999	10	XXXXXXXXXXXX
89.99999	8	XXXXXXXXXX
93.99999	7	XXXXXXXXXX
97.99999	6	XXXXXXX
102.0000	7	XXXXXXXXXX

200

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
23.28542	103.7892	80.50382	56.95843	55.50011	577

HISTOGRAM FOR VARIABLE NO. 18 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
-1.650000	8	XXXXXXXXXX
-0.5500000	37	XX
0.5500000	32	XX
1.650000	20	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
2.750000	10	XXXXXXXXXXXX
3.850000	8	XXXXXXXXXX
4.950000	9	XXXXXXXXXX
6.050000	5	XXXXXX
7.150000	4	XXXX

8.250000	3	XXX
9.350000	4	XXXX
10.45000	3	XXX
11.55000	7	XXXXXXXX
12.65000	9	XXXXXXXXXX
13.75000	7	XXXXXXXX
14.85000	5	XXXXX
15.95000	5	XXXXX
17.05000	5	XXXXX
18.15000	8	XXXXXXXX
19.25000	9	XXXXXXXXXX
20.35000	2	XX

200

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-1.207170	19.89481	21.10198	5.795099	2.504184	46.

HISTOGRAM FOR VARIABLE NO. 19 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
0.420000E-01	15	XXXXXXXXXXXXXXXXXX
0.700000E-01	0	
0.980000E-01	14	XXXXXXXXXXXXXXXXXX
0.1260000	0	
0.1540000	14	XXXXXXXXXXXXXXXXXX
0.1820000	14	XXXXXXXXXXXXXXXXXX
0.2100000	14	XXXXXXXXXXXXXXXXXX
0.2380000	29	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.2660000	15	XXXXXXXXXXXXXXXXXX
0.2940000	13	XXXXXXXXXXXXXXXXXX
0.3220000	0	
0.3500000	15	XXXXXXXXXXXXXXXXXX
0.3780000	14	XXXXXXXXXXXXXXXXXX
0.4060000	0	
0.4340000	14	XXXXXXXXXXXXXXXXXX
0.4620000	0	
0.4900000	0	
0.5180000	0	
0.5460000	14	XXXXXXXXXXXXXXXXXX
0.5740000	0	
0.6020000	15	XXXXXXXXXXXXXXXXXX

200

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.5080000E-01	0.6096000	0.5588000	0.2948792	0.2651150	0.24

HISTOGRAM FOR VARIABLE NO. 20 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.				
0.975000	60	XX			
1.125000	0				
1.275000	0				
1.425000	0				
1.575000	0				
1.725000	0				
1.875000	0				
2.025000	30	XX			
2.175000	0				
2.325000	0				
2.475000	0				
2.625000	0				
2.775000	0				
2.925000	40	XX			
3.075001	0				
3.225001	0				
3.375001	0				
3.525001	0				
3.675001	0				
3.825001	0				
3.975001	70	XX			
	200				
MIN	MAX	RANGE	MEAN	MEDIAN	VAR
1.000000	4.000000	3.000000	2.600000	3.000000	1.5

HISTOGRAM FOR VARIABLE NO. 21 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.				
-8.750003	26	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX			
-6.250002	0				
-3.750002	0				
-1.250001	0				
1.250000	26	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX			
3.750000	0				
6.250001	0				
8.750002	52	XX			
11.25000	0				
13.75000	0				
16.25000	0				
18.75000	0				

```

21.25000      0
23.75000      30  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
26.25000      0
28.75000      0
31.25000      0
33.75000      30  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
36.25000      0
38.75000      36  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
                200

```

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-10.00000	40.00000	50.00000	16.79000	8.000000	289

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RAW

```

1  1.0000
2  0.0057  1.0000
3  0.0007 -0.0037  1.0000
4  0.0592 -0.0277  0.0036  1.0000
5 -0.0016 -0.0607 -0.0530 -0.0436  1.0000
6 -0.0841  0.0207  0.0152 -0.0331 -0.0104  1.0000
7 -0.0211 -0.0006 -0.0025  0.0369  0.0078  0.0191  1.0000
8 -0.0325  0.0127 -0.0151 -0.0530  0.0220 -0.0425 -0.0179  1.0000
9 -0.0069  0.0248 -0.0010 -0.0768  0.0575  0.0681  0.0138 -0.0123  1.0000
10 -0.0317  0.0599  0.0621 -0.0237  0.0247 -0.0407 -0.1063 -0.0208  0.0266  1.
11  0.0317  0.0090 -0.0414 -0.0610  0.0330 -0.0750 -0.0417  0.0079  0.0714  0.
12 -0.0335  0.0318  0.0421  0.0265  0.1490  0.1309 -0.0478 -0.0411  0.0277  0.
13 -0.0083 -0.0083  0.0035  0.0506 -0.0011  0.0137  0.0534  0.0229 -0.0175 -0.
14  0.0137 -0.0204 -0.0386 -0.0357 -0.0384  0.0112  0.0072  0.0480 -0.0039 -0.
15 -0.0106  0.0073  0.0091 -0.0375  0.0212 -0.0795  0.0044  0.0086 -0.0265 -0.
16  0.0073  0.0008 -0.0134 -0.0734 -0.0768  0.1064 -0.0328  0.0099 -0.0176 -0.
17  0.0330  0.0233  0.0188 -0.0187 -0.0715 -0.0194 -0.0091 -0.0259 -0.0111  0.
18  0.0288 -0.0147  0.0037 -0.0115  0.0196 -0.0871  0.0188  0.0046  0.0206 -0.
19 -0.0178 -0.0003  0.0286 -0.0155  0.0247 -0.0421 -0.0247  0.0031 -0.0224  0.
20  0.0297 -0.0220  0.0047  0.0470  0.0313 -0.0441  0.0137  0.0037  0.0103  0.
21 -0.0241 -0.0529  0.0025  0.0420  0.0159  0.0462 -0.0469 -0.0277 -0.0247 -0.
                1         2         3         4         5         6         7         8         9

```

VARIABLES

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RAW

```

16  1.0000
17  0.0212  1.0000
18  0.0646 -0.0171  1.0000
19  0.0105 -0.0064 -0.0021  1.0000
20 -0.0315 -0.0598  0.0432  0.0103  1.0000
21 -0.0416 -0.0136  0.0221  0.0071 -0.0355  1.0000

```


THE SAMPLE INPUT VECTORS WILL BE PRINTED ALONG WITH THEIR CORRESPONDING RANKS
HISTOGRAMS OF THE ACTUAL SAMPLE WILL BE PLOTTED FOR EACH INPUT VARIABLE
THE CORRELATION MATRICES (RAW DATA AND RANK CORRELATIONS) WILL BE PRINTED

VARIABLE	DISTRIBUTION	RANGE	LABEL		
1	NORMAL	5.0000E-02 TO	0.2000	GLOBAL	DISPPERC
2	LOGNORMAL	1.0000E-02 TO	100.0	COLLOID	CONC
3	UNIFORM	4.8000E-02 TO	9.600	WAS AREA	TAUFAIL
4	LOGUNIFORM	1.0000E-17 TO	1.0000E-12	WAS AREA	SPPERM
5	USER SUPPLIED DISTRIBUTION		(CUMULATIVE)	BOREHOLE	
6	USER SUPPLIED DISTRIBUTION		(DATA)	CULEBRA POR	
7	USER SUPPLIED DISTRIBUTION		(DELTA)	BOREHOLE D	

INPUT RANK CORRELATION MATRIX

1	1.0000					
2	0.0000	1.0000				
3	0.9990	0.0000	1.0000			
4	0.0000	0.0000	0.0000	1.0000		
5	0.0000	0.9500	0.0000	0.0000	1.0000	
6	0.0000	0.0000	0.0000	0.8000	0.0000	1.0000
	1	2	3	4	5	6

VARIABLES

LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(1)	X(2)	X(3)	X(4)	X(5)	X(6)	X(7)
1	1.513E-01	2.679E-01	7.622E+00	5.768E-13	6.905E+00	2.048E-01	2.191E-0
2	5.678E-02	8.812E+00	2.050E-01	2.381E-14	1.207E+01	2.035E-01	1.016E-0
3	1.708E-01	2.590E-02	8.869E+00	6.471E-15	4.680E+00	1.397E-01	4.445E-0
4	1.528E-01	6.707E+00	7.790E+00	1.652E-14	9.321E+00	1.460E-01	1.016E-0
5	1.548E-01	4.771E-01	7.887E+00	2.416E-15	6.983E+00	1.261E-01	2.286E-0
6	1.003E-01	1.124E+00	2.163E+00	2.967E-16	8.299E+00	1.252E-01	3.048E-0
7	1.381E-01	2.813E-01	6.417E+00	1.076E-17	6.521E+00	1.049E-01	4.445E-0
8	9.516E-02	1.292E+00	1.739E+00	2.106E-14	7.755E+00	1.633E-01	5.588E-0
9	9.371E-02	1.764E+00	1.542E+00	2.411E-13	8.653E+00	1.559E-01	2.286E-0
10	1.394E-01	3.279E+00	6.365E+00	1.308E-16	9.846E+00	1.126E-01	4.445E-0
11	1.291E-01	1.241E-01	5.344E+00	3.323E-13	5.039E+00	2.063E-01	6.096E-0
12	1.256E-01	9.872E-01	4.839E+00	1.288E-17	8.131E+00	9.729E-02	6.096E-0
13	1.648E-01	1.449E+01	8.404E+00	1.412E-15	1.456E+01	1.355E-01	3.810E-0
14	1.272E-01	3.573E+00	5.054E+00	3.896E-17	1.004E+01	1.232E-01	5.588E-0
15	1.465E-01	2.691E+01	7.247E+00	7.787E-16	1.093E+01	1.177E-01	3.048E-0
16	1.307E-01	2.160E+01	5.408E+00	1.504E-13	1.250E+01	1.371E-01	4.445E-0
17	2.000E-01	5.165E+00	9.514E+00	2.151E-17	8.617E+00	9.193E-02	1.016E-0
18	1.694E-01	4.127E-01	8.733E+00	5.136E-13	6.619E+00	1.795E-01	3.492E-0
19	1.433E-01	7.694E+00	6.928E+00	5.381E-14	1.033E+01	1.617E-01	2.191E-0
20	1.564E-01	6.363E+01	8.060E+00	2.650E-13	2.253E+01	1.617E-01	3.810E-0

21	6.799E-02	5.629E+00	3.735E-01	2.600E-15	9.443E+00	1.446E-01	6.096E-0
22	1.617E-01	7.332E-01	8.581E+00	6.329E-17	6.844E+00	1.009E-01	3.048E-0
23	9.753E-02	8.488E-02	1.961E+00	4.368E-16	6.690E+00	1.061E-01	5.080E-0
24	1.462E-01	3.562E-01	7.152E+00	2.222E-16	7.538E+00	1.214E-01	4.445E-0
25	8.291E-02	7.549E-01	1.164E+00	5.577E-16	8.047E+00	1.153E-01	3.810E-0
26	1.181E-01	4.778E-02	4.318E+00	5.227E-16	5.281E+00	1.709E-01	2.286E-0
27	1.344E-01	1.641E+00	5.901E+00	8.626E-17	7.933E+00	1.653E-01	2.286E-0
28	1.421E-01	1.107E+01	6.546E+00	2.033E-16	1.147E+01	1.225E-01	2.794E-0
29	1.041E-01	2.132E-01	2.806E+00	1.307E-15	6.434E+00	1.209E-01	1.937E-0
30	1.751E-01	6.120E-01	9.027E+00	1.708E-15	7.373E+00	1.783E-01	1.524E-0
31	1.080E-01	3.131E-02	2.939E+00	3.799E-14	4.943E+00	1.622E-01	3.492E-0
32	1.320E-01	1.801E+00	5.574E+00	6.583E-14	8.932E+00	1.752E-01	1.016E-0
33	1.169E-01	1.340E-01	3.837E+00	1.881E-13	5.725E+00	1.788E-01	3.048E-0
34	1.847E-01	2.063E+00	9.235E+00	5.699E-17	1.110E+01	9.960E-02	1.524E-0
35	1.064E-01	1.858E+01	2.618E+00	8.350E-13	1.404E+01	1.781E-01	2.794E-0
36	1.220E-01	1.777E-01	4.418E+00	1.561E-14	6.884E+00	1.136E-01	3.810E-0
37	1.242E-01	5.108E-01	4.662E+00	1.465E-16	6.669E+00	1.410E-01	5.080E-0
38	1.365E-01	1.010E+01	6.112E+00	7.603E-15	1.306E+01	1.231E-01	3.492E-0
39	8.529E-02	5.315E-01	1.198E+00	1.803E-13	7.449E+00	2.178E-01	4.445E-0
40	1.338E-01	1.975E+00	6.014E+00	4.210E-14	7.686E+00	1.455E-01	1.937E-0
41	1.139E-01	1.083E-01	3.703E+00	2.744E-14	6.373E+00	1.773E-01	5.080E-0
42	5.000E-02	1.310E+01	1.035E-01	1.341E-13	1.383E+01	2.075E-01	5.080E-0
43	7.126E-02	4.333E+01	5.453E-01	9.036E-16	1.862E+01	1.464E-01	6.096E-0
44	1.479E-01	2.068E-01	7.354E+00	7.758E-14	6.089E+00	1.596E-01	1.524E-0
45	1.493E-01	2.214E+00	7.455E+00	6.536E-13	9.075E+00	2.311E-01	2.508E-0
46	8.768E-02	2.482E+00	1.012E+00	3.257E-17	8.344E+00	1.185E-01	2.286E-0
47	9.127E-02	3.152E-01	1.670E+00	5.164E-17	7.854E+00	1.091E-01	2.794E-0
48	7.328E-02	1.220E+00	5.965E-01	2.243E-17	7.307E+00	7.738E-02	1.524E-0
49	1.281E-01	4.291E+00	5.194E+00	1.109E-13	1.179E+01	1.792E-01	2.286E-0
50	1.207E-01	1.576E-01	4.095E+00	3.866E-15	6.066E+00	1.326E-01	2.794E-0
51	7.722E-02	3.026E+00	7.965E-01	9.780E-15	8.361E+00	1.433E-01	1.016E-0
52	1.788E-01	4.285E-01	9.130E+00	1.214E-14	7.866E+00	1.698E-01	5.588E-0
53	1.126E-01	8.148E-01	3.307E+00	7.707E-17	7.654E+00	1.223E-01	2.508E-0
54	8.186E-02	3.940E+00	8.700E-01	3.814E-16	1.238E+01	1.440E-01	1.937E-0
55	1.605E-01	3.781E-01	8.309E+00	6.213E-14	7.591E+00	1.917E-01	1.524E-0
56	1.368E-01	1.041E+00	6.241E+00	3.579E-13	7.273E+00	2.483E-01	2.794E-0
57	1.883E-01	8.697E-01	9.386E+00	7.047E-16	8.246E+00	1.641E-01	2.508E-0
58	1.094E-01	3.218E-01	3.228E+00	4.207E-15	6.770E+00	1.311E-01	2.191E-0
59	1.191E-01	1.511E+00	4.134E+00	4.156E-17	8.021E+00	1.289E-01	1.016E-0
60	1.100E-01	2.871E+00	3.424E+00	1.593E-17	1.030E+01	8.579E-02	1.937E-0
61	1.148E-01	6.294E+00	3.595E+00	1.029E-16	1.053E+01	1.084E-01	3.048E-0
62	1.250E-01	1.478E-01	4.973E+00	1.923E-15	5.687E+00	1.219E-01	6.096E-0

63	1.012E-01	2.335E-01	2.374E+00	8.606E-13	6.495E+00	1.953E-01	3.492E-0
64	9.012E-02	9.451E-01	1.369E+00	2.567E-17	7.149E+00	1.203E-01	3.492E-0
65	1.228E-01	6.967E-02	4.516E+00	1.441E-17	6.323E+00	1.051E-01	2.508E-0
66	1.450E-01	4.445E+00	6.882E+00	1.079E-15	9.641E+00	1.617E-01	5.080E-0
67	1.051E-01	1.179E-02	2.537E+00	2.514E-16	4.469E+00	1.038E-01	2.508E-0
68	1.401E-01	1.000E+02	6.764E+00	5.846E-15	1.726E+01	1.866E-01	6.096E-0
69	9.847E-02	5.560E-02	1.950E+00	4.117E-13	5.353E+00	2.028E-01	3.492E-0
70	1.122E-01	8.908E-02	3.029E+00	5.245E-15	7.054E+00	1.619E-01	5.588E-0
71	1.579E-01	5.735E-01	8.081E+00	1.112E-14	7.212E+00	1.238E-01	1.937E-0
72	1.659E-01	6.905E-01	8.615E+00	8.854E-14	7.078E+00	1.783E-01	4.445E-0
73	1.165E-01	1.365E+00	3.951E+00	3.386E-14	7.490E+00	1.787E-01	2.191E-0
74	1.327E-01	2.580E+00	5.753E+00	1.761E-16	8.173E+00	5.871E-02	1.937E-0
75	1.031E-01	1.763E-02	2.331E+00	3.404E-15	4.264E+00	1.535E-01	2.508E-0

RANKS OF LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(1)	X(2)	X(3)	X(4)	X(5)	X(6)	X(7)
1	60.	19.	60.	72.	23.	70.	25
2	2.	65.	2.	51.	66.	69.	9
3	70.	3.	70.	43.	3.	35.	62
4	61.	63.	61.	49.	54.	41.	9
5	62.	27.	62.	36.	24.	29.	30
6	17.	40.	17.	23.	47.	28.	46
7	50.	20.	51.	1.	16.	9.	62
8	14.	42.	14.	50.	38.	51.	68
9	13.	46.	12.	66.	51.	44.	30
10	51.	55.	50.	17.	57.	14.	62
11	42.	11.	42.	68.	5.	71.	73
12	39.	38.	38.	2.	44.	5.	73
13	67.	69.	66.	33.	72.	33.	57
14	40.	56.	40.	9.	58.	26.	68
15	57.	72.	57.	29.	62.	17.	46
16	43.	71.	43.	63.	68.	34.	62
17	75.	60.	75.	5.	50.	4.	9
18	69.	25.	69.	71.	17.	64.	52
19	54.	64.	55.	56.	60.	47.	25
20	63.	74.	63.	67.	75.	48.	57
21	3.	61.	3.	37.	55.	39.	73
22	66.	33.	67.	13.	21.	7.	46
23	15.	8.	16.	25.	19.	11.	3
24	56.	23.	56.	21.	34.	21.	62
25	8.	34.	9.	27.	43.	16.	57
26	32.	5.	34.	26.	6.	55.	30
27	47.	45.	46.	15.	41.	53.	30

28	53.	67.	52.	20.	64.	24.	41
29	20.	17.	22.	32.	14.	20.	20
30	71.	31.	71.	34.	31.	60.	14
31	23.	4.	23.	54.	4.	50.	52
32	44.	47.	44.	58.	52.	56.	9
33	31.	12.	30.	65.	9.	62.	46
34	73.	49.	73.	12.	63.	6.	14
35	22.	70.	21.	74.	71.	58.	41
36	35.	15.	35.	48.	22.	15.	57
37	37.	28.	37.	18.	18.	36.	3
38	48.	66.	48.	44.	69.	25.	52
39	9.	29.	10.	64.	32.	73.	62
40	46.	48.	47.	55.	37.	40.	20
41	28.	10.	29.	52.	13.	57.	3
42	1.	68.	1.	62.	70.	72.	3
43	4.	73.	4.	30.	74.	42.	73
44	58.	16.	58.	59.	11.	45.	14
45	59.	50.	59.	73.	53.	74.	36
46	10.	51.	8.	8.	48.	18.	30
47	12.	21.	13.	11.	39.	13.	41
48	5.	41.	5.	6.	30.	2.	14
49	41.	58.	41.	61.	65.	63.	30
50	34.	14.	32.	39.	10.	32.	41
51	6.	54.	6.	45.	49.	37.	9
52	72.	26.	72.	47.	40.	54.	68
53	27.	35.	26.	14.	36.	23.	36
54	7.	57.	7.	24.	67.	38.	20
55	65.	24.	65.	57.	35.	66.	14
56	49.	39.	49.	69.	29.	75.	41
57	74.	36.	74.	28.	46.	52.	36
58	24.	22.	25.	40.	20.	31.	25
59	33.	44.	33.	10.	42.	30.	9
60	25.	53.	27.	4.	59.	3.	20
61	29.	62.	28.	16.	61.	12.	46
62	38.	13.	39.	35.	8.	22.	73
63	18.	18.	19.	75.	15.	67.	52
64	11.	37.	11.	7.	27.	19.	52
65	36.	7.	36.	3.	12.	10.	36
66	55.	59.	54.	31.	56.	46.	3
67	21.	1.	20.	22.	2.	8.	36
68	52.	75.	53.	42.	73.	65.	73
69	16.	6.	15.	70.	7.	68.	52

42.49999	1	X
47.49999	0	
52.49999	0	
57.49999	0	
62.49999	1	X
67.49998	0	
72.49998	0	
77.49998	0	
82.49998	0	
87.49998	0	
92.49998	0	
97.49998	0	
102.5000	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.1179351E-01	100.0001	99.98830	5.677361	0.9872297	214

HISTOGRAM FOR VARIABLE NO. 3 UNIFORM DISTRIBUTION

MIDPOINT	FREQ.	
0.2349999	3	XXX
0.7049998	4	XXXX
1.175000	4	XXXX
1.645000	3	XXX
2.115000	4	XXXX
2.584999	4	XXXX
3.054999	3	XXX
3.524999	4	XXXX
3.994999	4	XXXX
4.464999	4	XXXX
4.934999	3	XXX
5.404998	4	XXXX
5.874998	3	XXX
6.344998	5	XXXXX
6.814998	3	XXX
7.284997	4	XXXX
7.754997	3	XXX
8.224998	4	XXXX
8.694998	4	XXXX
9.164998	4	XXXX
9.634998	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.1035329	9.514432	9.410899	4.824547	4.839019	7.5

HISTOGRAM FOR VARIABLE NO. 4 LOGUNIFORM DISTRIBUTION

MIDPOINT	FREQ.	
0.2149999E-13	55	XX
0.6449998E-13	4	XXXX
0.1075000E-12	2	XX
0.1505000E-12	2	XX
0.1934999E-12	2	XX
0.2364999E-12	1	X
0.2794999E-12	1	X
0.3224999E-12	1	X
0.3654999E-12	1	X
0.4084999E-12	1	X
0.4514999E-12	0	
0.4944999E-12	1	X
0.5374999E-12	0	
0.5804999E-12	1	X
0.6234999E-12	0	
0.6664999E-12	1	X
0.7095000E-12	0	
0.7525000E-12	0	
0.7955000E-12	0	
0.8385000E-12	1	X
0.8815000E-12	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.1076223E-16	0.8605560E-12	0.8605453E-12	0.8621589E-13	0.3403765E-14	0.34

HISTOGRAM FOR VARIABLE NO. 5 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
4.094997	2	XX
5.004997	5	XXXXX
5.914996	5	XXXXX
6.824996	17	XXXXXXXXXXXXXXXXXXXX
7.734995	16	XXXXXXXXXXXXXXXXXXXX
8.644995	8	XXXXXXXX
9.554995	4	XXXX
10.46499	4	XXXX
11.37499	4	XXXX
12.28499	3	XXX
13.19499	1	X
14.10499	2	XX
15.01499	1	X
15.92499	0	

16.83499	1	X
17.74499	0	
18.65499	1	X
19.56499	0	
20.47499	0	
21.38499	0	
22.29499	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
4.263539	22.53333	18.26979	8.638453	7.755095	10.

HISTOGRAM FOR VARIABLE NO. 6 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.
0.6174996E-01	1 X
0.7124996E-01	0
0.8074996E-01	1 X
0.9024996E-01	2 XX
0.9974995E-01	4 XXXX
0.1092499	7 XXXXXXXX
0.1187499	11 XXXXXXXXXXXX
0.1282499	6 XXXXXX
0.1377499	4 XXXX
0.1472499	6 XXXXXX
0.1567499	3 XXX
0.1662499	10 XXXXXXXXXXXX
0.1757499	9 XXXXXXXXXXXX
0.1852499	1 X
0.1947499	2 XX
0.2042499	5 XXXXX
0.2137499	1 X
0.2232499	0
0.2327499	1 X
0.2422499	0
0.2517499	1 X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.5870660E-01	0.2482859	0.1895793	0.1467121	0.1439527	0.14

HISTOGRAM FOR VARIABLE NO. 7 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.
0.4200000E-01	5 XXXXX
0.7000001E-01	0
0.9800001E-01	6 XXXXXX
0.1260000	0

0.1540000	5	XXXXX
0.1820000	6	XXXXXXX
0.2100000	4	XXXX
0.2380000	12	XXXXXXXXXXXXXXXX
0.2660000	5	XXXXX
0.2940000	5	XXXXX
0.3220000	0	
0.3500000	6	XXXXXXX
0.3780000	4	XXXX
0.4060000	0	
0.4340000	7	XXXXXXX
0.4620000	0	
0.4900000	0	
0.5180000	0	
0.5460000	4	XXXX
0.5740000	0	
0.6020000	6	XXXXXXX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.5080000E-01	0.6096000	0.5588000	0.2944717	0.2508300	0.24

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RAW

1	1.0000							
2	0.0316	1.0000						
3	0.9828	0.0825	1.0000					
4	0.0085	0.0298	0.0098	1.0000				
5	-0.0292	0.7781	0.0292	0.0423	1.0000			
6	-0.0208	0.1069	0.0253	0.5737	0.0447	1.0000		
7	0.0039	0.2746	0.0024	0.0463	0.1181	0.0240	1.0000	
	1	2	3	4	5	6	7	

VARIABLES

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RANK

1	1.0000							
2	0.0508	1.0000						
3	0.9993	0.0471	1.0000					
4	0.0600	-0.0393	0.0604	1.0000				
5	0.0272	0.9499	0.0229	-0.0576	1.0000			
6	0.0331	-0.0238	0.0327	0.8124	-0.0277	1.0000		
7	0.0149	-0.0538	0.0103	0.0556	-0.0263	0.0066	1.0000	
	1	2	3	4	5	6	7	

VARIABLES

OUTPUT FILE FOR LHS TEST 4

RANDOM SEED = 933090934

NUMBER OF VARIABLES = 21

NUMBER OF OBSERVATIONS = 75

AN INPUT CORRELATION MATRIX HAS BEEN SPECIFIED

THE SAMPLE INPUT VECTORS WILL BE PRINTED ALONG WITH THEIR CORRESPONDING RANKS

HISTOGRAMS OF THE ACTUAL SAMPLE WILL BE PLOTTED FOR EACH INPUT VARIABLE

THE CORRELATION MATRICES (RAW DATA AND RANK CORRELATIONS) WILL BE PRINTED

VARIABLE	DISTRIBUTION	RANGE	LABEL		
1	UNIFORM	0.0000E+00 TO	1.000	UNIFMAT2	UNIFPRP2
2	NORMAL	-3.6737E-02 TO	8.3264E-02	NORMMAT3	NORMPRP3
3	LOGNORMAL	1.0000E-03 TO	350.0	LOGNMAT2	LOGNPRP2
4	UNIFORM	-0.5000 TO	0.5000	UNIFMAT1	UNIFPRP1
5	USER SUPPLIED DISTRIBUTION		(DELTA)		DELTMAT3 D
6	UNIFORM	12.50 TO	500.0	UNIFMAT3	UNIFPRP3
7	LOGUNIFORM	1.0000E-17 TO	1.0000E-11	LOGUMAT1	LOGUPRP1
8	USER SUPPLIED DISTRIBUTION		(DATA)		DATAMAT2 DAT
9	NORMAL	0.0000E+00 TO	0.2000	NORMMAT1	NORMPRP1
10	USER SUPPLIED DISTRIBUTION		(DELTA)		DELTMAT1 D
11	LOGUNIFORM	5.6000E+13 TO	5.6000E+15	LOGUMAT3	LOGUPRP3
12	USER SUPPLIED DISTRIBUTION		(CUMULATIVE)		CUMMAT1
13	NORMAL	577.0 TO	1042.	NORMMAT2	NORMPRP2
14	USER SUPPLIED DISTRIBUTION		(CUMULATIVE)		CUMMAT3
15	LOGNORMAL	1.0000E-02 TO	2.130	LOGNMAT1	LOGNPRP1
16	USER SUPPLIED DISTRIBUTION		(DATA)		DATAMAT1 DAT
17	LOGNORMAL	1.0000E-04 TO	5.2500E+04	LOGNMAT3	LOGNPRP3
18	USER SUPPLIED DISTRIBUTION		(DATA)		DATAMAT3 DAT
19	USER SUPPLIED DISTRIBUTION		(CUMULATIVE)		CUMMAT2
20	LOGUNIFORM	1.0000E-06 TO	1000.	LOGUMAT2	LOGUPRP2
21	USER SUPPLIED DISTRIBUTION		(DELTA)		DELTMAT2 D

INPUT RANK CORRELATION MATRIX

1	1.0000								
2	0.0000	1.0000							
3	0.9990	0.0000	1.0000						
4	0.0000	0.0000	0.0000	1.0000					
5	0.0000	0.9500	0.0000	0.0000	1.0000				
6	0.0000	0.0000	0.0000	0.8000	0.0000	1.0000			
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000		
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6500	1.0000	
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6500	0.6500	1.0000
	1	2	3	4	5	6	7	8	9

VARIABLES

LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(1)	X(2)	X(3)	X(4)	X(5)	X(6)	X(7)
---------	------	------	------	------	------	------	------

1	8.978E-01	1.602E-02	1.899E+01	-1.699E-02	8.000E+00	2.690E+02	2.533E-1
2	5.078E-01	1.844E-02	8.610E-01	1.647E-01	8.000E+00	2.754E+02	2.078E-1
3	6.426E-01	4.806E-02	1.682E+00	-5.350E-02	4.000E+01	1.218E+02	8.508E-1
4	3.457E-01	1.222E-02	1.542E-01	4.107E-01	2.000E+00	4.397E+02	8.065E-1
5	3.966E-01	1.687E-02	2.403E-01	-9.337E-02	8.000E+00	4.087E+02	1.702E-1
6	7.451E-01	6.738E-03	3.887E+00	-1.088E-01	8.000E+00	1.748E+02	3.954E-1
7	6.720E-01	4.313E-03	1.931E+00	-4.298E-01	2.000E+00	4.964E+01	4.678E-1
8	6.804E-01	1.059E-02	2.139E+00	-7.002E-02	8.000E+00	1.402E+02	4.975E-1
9	7.608E-01	6.330E-02	4.720E+00	-4.596E-01	4.000E+01	2.508E+01	2.479E-1
10	8.465E-01	2.660E-02	8.935E+00	-3.819E-01	8.000E+00	3.455E+01	1.896E-1
11	8.350E-01	-2.935E-02	9.154E+00	-1.719E-01	-1.000E+01	1.024E+02	3.549E-1
12	2.986E-01	3.362E-02	1.018E-01	-4.335E-01	3.400E+01	7.070E+01	8.296E-1
13	9.680E-01	1.922E-02	7.636E+01	-2.055E-01	8.000E+00	2.422E+02	4.144E-1
14	2.485E-01	3.769E-02	1.092E-01	4.395E-02	4.000E+01	1.630E+02	1.262E-1
15	1.717E-02	6.100E-03	1.697E-03	-7.672E-02	8.000E+00	2.957E+02	2.326E-1
16	5.005E-01	4.270E-02	6.585E-01	-2.767E-01	2.300E+01	1.468E+02	1.903E-1
17	9.224E-01	4.113E-02	2.985E+01	-3.128E-01	4.000E+01	2.596E+02	4.682E-1
18	4.627E-01	1.173E-02	4.414E-01	-2.338E-02	8.000E+00	3.625E+02	2.181E-1
19	5.506E-01	-3.459E-02	7.726E-01	2.478E-02	-1.000E+01	3.017E+02	1.161E-1
20	9.752E-01	7.237E-02	1.454E+02	4.421E-01	4.000E+01	3.767E+02	4.252E-1
21	1.235E-01	-2.187E-02	2.255E-02	-3.974E-01	-1.000E+01	1.905E+02	1.336E-1
22	4.902E-01	1.451E-02	4.739E-01	-3.397E-01	2.000E+00	4.245E+01	1.390E-1
23	5.854E-01	2.864E-02	1.019E+00	4.631E-01	8.000E+00	4.884E+02	9.359E-1
24	8.649E-01	3.093E-02	1.385E+01	1.168E-01	2.300E+01	2.243E+02	3.895E-1
25	5.378E-01	4.224E-02	6.980E-01	-2.508E-01	3.400E+01	1.115E+02	1.221E-1
26	6.396E-01	-2.926E-03	1.523E+00	1.746E-02	2.000E+00	1.594E+02	9.368E-1
27	3.759E-01	2.586E-02	2.884E-01	-1.563E-01	2.300E+01	2.129E+02	2.949E-1
28	3.850E-02	2.732E-02	3.968E-03	1.877E-01	2.300E+01	1.333E+02	1.060E-1
29	5.698E-01	3.700E-02	9.022E-01	-4.181E-01	4.000E+01	2.797E+02	1.349E-1
30	4.464E-01	2.479E-02	4.106E-01	2.637E-01	8.000E+00	4.190E+02	5.675E-1
31	5.195E-03	1.362E-02	1.000E-03	-4.318E-02	8.000E+00	2.070E+02	5.570E-1
32	9.583E-02	1.503E-02	1.785E-02	4.522E-01	2.000E+00	4.811E+02	7.396E-1
33	4.004E-01	5.458E-02	3.138E-01	-1.217E-01	4.000E+01	3.114E+02	3.335E-1
34	1.773E-01	4.723E-02	4.651E-02	-1.837E-01	3.400E+01	3.304E+02	6.682E-1
35	6.917E-02	3.874E-02	1.396E-02	1.093E-01	3.400E+01	2.547E+02	3.385E-1
36	5.433E-02	-1.145E-02	7.820E-03	-4.682E-01	-1.000E+01	6.395E+01	8.853E-1
37	9.045E-02	2.971E-02	1.215E-02	-1.507E-01	2.300E+01	3.121E+02	5.232E-1
38	4.776E-02	2.253E-02	6.848E-03	-3.574E-01	8.000E+00	5.373E+01	1.337E-1
39	9.940E-01	8.492E-03	3.500E+02	-2.976E-01	8.000E+00	2.367E+02	9.421E-1
40	7.927E-01	-8.873E-03	5.560E+00	-4.936E-01	2.000E+00	9.116E+01	2.710E-1
41	2.300E-01	6.616E-02	5.896E-02	-3.488E-01	4.000E+01	1.535E+02	1.060E-1
42	8.060E-01	-8.098E-04	6.615E+00	7.619E-02	8.000E+00	2.521E+02	1.899E-1

43	7.475E-01	2.310E-02	2.935E+00	2.587E-01	8.000E+00	4.240E+02	2.132E-1
44	1.477E-01	2.060E-02	4.305E-02	2.249E-01	8.000E+00	1.765E+02	6.681E-1
45	1.971E-01	3.127E-03	5.825E-02	1.387E-01	2.300E+01	7.164E+01	2.307E-1
46	6.081E-01	3.066E-02	1.413E+00	2.780E-01	2.300E+01	3.403E+02	1.094E-1
47	2.584E-01	-1.648E-03	8.788E-02	-2.199E-01	2.000E+00	3.055E+01	1.843E-1
48	9.160E-01	2.144E-02	2.313E+01	-2.668E-01	8.000E+00	7.806E+01	5.946E-1
49	7.154E-01	-2.434E-02	2.822E+00	3.255E-01	-1.000E+01	4.107E+02	3.083E-1
50	1.396E-01	7.560E-04	2.989E-02	6.392E-03	2.000E+00	1.845E+02	1.899E-1
51	5.274E-01	2.732E-03	5.980E-01	4.870E-01	2.000E+00	4.977E+02	2.552E-1
52	3.205E-01	-8.243E-03	1.925E-01	-2.384E-01	-1.000E+01	2.282E+02	1.564E-1
53	4.734E-01	7.737E-02	5.265E-01	-2.306E-01	4.000E+01	2.167E+02	5.913E-1
54	7.326E-01	2.379E-02	3.568E+00	5.337E-02	2.300E+01	1.946E+02	8.042E-1
55	4.154E-01	5.339E-02	3.488E-01	2.894E-01	4.000E+01	3.540E+02	1.154E-1
56	2.215E-01	-5.701E-03	8.443E-02	6.219E-02	2.000E+00	3.459E+02	1.394E-1
57	7.746E-01	5.810E-02	4.288E+00	4.229E-01	4.000E+01	3.958E+02	1.295E-1
58	1.659E-01	4.985E-02	3.709E-02	4.043E-01	3.400E+01	4.617E+02	2.323E-1
59	5.949E-01	1.960E-02	1.163E+00	3.512E-01	2.300E+01	3.324E+02	2.890E-1
60	2.819E-01	4.465E-02	1.433E-01	-1.304E-01	3.400E+01	3.727E+02	3.861E-1
61	3.139E-01	3.213E-02	1.809E-01	3.764E-01	2.300E+01	4.344E+02	9.502E-1
62	4.270E-01	3.985E-02	3.590E-01	2.462E-01	2.300E+01	3.973E+02	6.551E-1
63	9.524E-01	4.578E-02	5.515E+01	3.355E-01	3.400E+01	4.528E+02	5.257E-1
64	8.914E-01	-1.636E-02	1.797E+01	2.059E-01	-1.000E+01	3.852E+02	3.350E-1
65	1.090E-01	5.678E-02	2.367E-02	1.436E-01	3.400E+01	2.919E+02	6.056E-1
66	9.399E-01	3.561E-02	4.214E+01	2.159E-01	3.400E+01	4.436E+02	7.581E-1
67	8.727E-01	9.816E-03	1.218E+01	9.807E-02	8.000E+00	1.056E+02	7.063E-1
68	2.680E-01	8.221E-03	1.283E-01	4.843E-01	8.000E+00	4.744E+02	6.324E-1
69	3.658E-01	8.326E-02	2.608E-01	-4.780E-01	4.000E+01	1.292E+01	2.688E-1
70	6.150E-01	5.162E-02	1.298E+00	1.754E-01	4.000E+01	4.690E+02	4.512E-1
71	2.053E-01	3.511E-02	7.205E-02	3.549E-01	3.400E+01	3.223E+02	3.834E-1
72	3.508E-01	3.270E-02	2.107E-01	3.090E-01	2.300E+01	4.558E+02	2.271E-1
73	8.220E-01	-1.439E-02	7.339E+00	-3.226E-01	-1.000E+01	8.870E+01	1.623E-1
74	6.575E-01	6.134E-02	1.853E+00	-3.763E-01	4.000E+01	1.254E+02	4.454E-1
75	7.018E-01	-3.923E-03	2.556E+00	3.846E-01	-1.000E+01	3.647E+02	1.654E-1

LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(11)	X(12)	X(13)	X(14)	X(15)	X(16)	X(17)
1	8.872E+13	-6.241E+00	8.492E+02	-2.660E+00	4.174E-02	2.029E-01	6.437E+0
2	9.658E+13	-6.044E+00	7.625E+02	-3.689E+00	1.822E-01	1.390E-01	3.862E-0
3	8.455E+14	-5.457E+00	7.365E+02	-7.553E+00	6.360E-02	5.809E-02	3.870E+0
4	2.912E+15	-6.445E+00	9.178E+02	-4.768E+00	1.132E-01	1.184E-01	2.353E-0
5	2.531E+14	-6.277E+00	6.877E+02	-5.149E+00	3.975E-01	9.187E-02	4.524E-0
6	1.183E+15	-5.271E+00	8.345E+02	-4.242E+00	6.720E-01	1.546E-01	2.741E-0
7	1.249E+15	-6.924E+00	7.285E+02	-2.801E+00	2.703E-01	1.617E-01	8.703E+0

8	7.050E+14	-3.655E+00	8.084E+02	-2.595E+00	1.736E-01	1.265E-01	1.830E-0
9	1.291E+14	-7.640E+00	9.983E+02	-5.982E+00	1.397E-01	1.790E-01	1.278E+0
10	7.428E+13	-5.551E+00	7.887E+02	-3.278E+00	9.242E-01	1.042E-01	4.324E+0
11	3.391E+15	-4.828E+00	7.802E+02	-2.106E+00	4.637E-01	1.527E-01	3.360E+0
12	5.803E+14	-5.847E+00	7.104E+02	-2.554E+00	2.475E-01	1.616E-01	7.171E-0
13	6.401E+13	-6.421E+00	9.055E+02	-6.284E+00	2.019E-01	1.087E-01	4.221E-0
14	7.086E+13	-4.958E+00	8.679E+02	-6.881E+00	1.000E-02	1.453E-01	2.864E-0
15	3.679E+15	-5.152E+00	9.664E+02	-2.053E+00	2.091E-01	1.063E-01	5.112E-0
16	2.255E+14	-6.049E+00	8.867E+02	-2.459E+00	1.211E+00	1.165E-01	1.261E+0
17	2.402E+15	-5.658E+00	9.346E+02	-3.308E+00	1.166E-02	2.499E-01	1.360E-0
18	8.396E+13	-6.379E+00	8.224E+02	-6.119E+00	3.679E-02	1.630E-01	1.177E-0
19	1.008E+15	-7.611E+00	7.045E+02	-8.069E+00	8.599E-02	1.451E-01	8.775E+0
20	1.110E+14	-5.994E+00	7.205E+02	-3.166E+00	1.078E-01	8.774E-02	1.000E-0
21	7.833E+13	-6.729E+00	6.503E+02	-5.605E+00	4.282E-01	1.894E-01	7.377E-0
22	1.611E+15	-5.102E+00	7.538E+02	-7.913E+00	1.192E-01	1.716E-01	2.624E+0
23	4.254E+14	-4.876E+00	8.164E+02	-7.787E+00	7.859E-01	1.211E-01	3.678E-0
24	1.627E+14	-5.210E+00	9.749E+02	-7.708E+00	5.384E-01	1.461E-01	1.619E+0
25	2.715E+15	-5.648E+00	6.612E+02	-4.791E+00	9.795E-02	1.787E-01	3.439E-0
26	1.981E+14	-5.757E+00	9.090E+02	-7.511E+00	9.242E-02	1.231E-01	3.557E+0
27	3.931E+15	-7.263E+00	8.917E+02	-7.325E+00	3.780E-01	1.288E-01	1.956E+0
28	4.423E+15	-6.312E+00	8.990E+02	-2.334E+00	1.482E-01	1.435E-01	4.991E+0
29	4.564E+14	-5.736E+00	1.024E+03	-4.292E+00	2.848E-01	1.149E-01	6.471E-0
30	1.463E+15	-2.989E+00	7.582E+02	-5.864E+00	3.407E-01	1.784E-01	1.968E-0
31	9.576E+14	-5.712E+00	8.567E+02	-5.633E+00	9.303E-02	1.230E-01	7.821E+0
32	8.230E+14	-5.814E+00	7.839E+02	-6.640E+00	1.140E-01	1.781E-01	2.932E+0
33	4.694E+15	-6.509E+00	8.312E+02	-2.255E+00	2.551E-01	1.331E-01	6.857E+0
34	6.252E+13	-5.404E+00	9.215E+02	-6.407E+00	8.062E-02	1.783E-01	1.545E+0
35	6.487E+14	-5.265E+00	6.231E+02	-2.704E+00	4.944E-02	1.226E-01	9.958E-0
36	1.692E+14	-5.054E+00	7.235E+02	-5.269E+00	3.903E-02	1.782E-01	2.571E+0
37	5.228E+15	-5.492E+00	9.522E+02	-7.123E+00	4.547E-01	1.491E-01	6.398E+0
38	7.409E+14	-4.770E+00	8.045E+02	-7.959E+00	1.513E-01	1.791E-01	3.183E+0
39	5.289E+15	-5.441E+00	7.864E+02	-5.467E+00	4.941E-01	2.183E-01	6.558E-0
40	1.432E+15	-4.084E+00	8.825E+02	-5.312E+00	2.762E-02	1.195E-01	2.045E+0
41	1.415E+14	-5.935E+00	6.035E+02	-2.203E+00	4.737E-02	1.409E-01	1.929E+0
42	2.075E+15	-6.143E+00	7.419E+02	-8.433E+00	1.283E-01	1.804E-01	5.299E+0
43	2.797E+14	-5.199E+00	8.948E+02	-2.279E+00	1.901E-01	1.386E-01	3.793E+0
44	3.128E+14	-5.007E+00	6.945E+02	-4.981E+00	1.579E-01	1.654E-01	3.479E-0
45	3.369E+14	-5.332E+00	8.537E+02	-7.078E+00	1.715E+00	1.360E-01	1.609E+0
46	1.879E+15	-5.867E+00	7.647E+02	-5.082E+00	1.771E-01	2.076E-01	4.808E+0
47	1.805E+14	-6.554E+00	7.033E+02	-2.938E+00	2.140E-01	1.052E-01	1.022E-0
48	6.828E+14	-4.975E+00	8.200E+02	-4.644E+00	7.307E-02	1.211E-01	7.581E-0
49	2.945E+14	-5.323E+00	7.998E+02	-3.536E+00	1.652E-01	1.962E-01	1.204E+0

50	1.565E+14	-6.205E+00	9.272E+02	-3.009E+00	3.242E-02	1.038E-01	3.109E-0
51	9.421E+14	-7.812E+00	7.963E+02	-3.176E+00	2.242E-02	1.108E-01	4.981E-0
52	5.139E+14	-5.788E+00	7.506E+02	-8.304E+00	2.882E-01	1.253E-01	1.134E-0
53	1.704E+15	-5.602E+00	7.739E+02	-8.538E+00	3.286E-01	1.628E-01	2.270E-0
54	3.572E+14	-6.374E+00	5.770E+02	-4.499E+00	6.021E-02	1.617E-01	7.778E-0
55	4.239E+15	-6.561E+00	8.718E+02	-2.868E+00	1.357E-01	1.618E-01	2.448E+0
56	5.907E+13	-5.077E+00	8.640E+02	-4.063E+00	6.514E-01	9.943E-02	9.042E+0
57	5.520E+14	-5.362E+00	7.928E+02	-6.501E+00	2.221E-01	2.037E-01	1.574E-0
58	9.909E+13	-6.323E+00	8.419E+02	-7.272E+00	5.977E-01	2.061E-01	4.523E-0
59	1.076E+14	-6.076E+00	8.249E+02	-3.893E+00	2.583E-02	1.767E-01	2.739E+0
60	3.072E+15	-3.404E+00	7.331E+02	-6.766E+00	1.624E-02	1.021E-01	5.774E+0
61	2.149E+14	-4.524E+00	7.720E+02	-6.912E+00	2.130E+00	1.219E-01	1.202E+0
62	1.172E+14	-4.787E+00	8.137E+02	-2.764E+00	2.992E-02	1.612E-01	6.254E+0
63	1.788E+15	-4.860E+00	7.444E+02	-3.065E+00	7.742E-02	7.594E-02	1.153E+0
64	2.618E+15	-5.970E+00	8.383E+02	-3.945E+00	2.368E-01	1.158E-01	5.250E+0
65	1.370E+14	-6.124E+00	7.700E+02	-2.444E+00	9.655E-01	2.312E-01	1.465E+0
66	4.102E+14	-5.895E+00	6.396E+02	-2.128E+00	3.035E-01	1.672E-01	1.646E+0
67	1.346E+15	-5.139E+00	9.483E+02	-5.749E+00	5.245E-02	1.830E-01	5.716E+0
68	2.363E+14	-5.586E+00	1.038E+03	-2.960E+00	5.612E-02	2.059E-01	1.415E+0
69	2.344E+15	-7.211E+00	8.782E+02	-8.228E+00	8.388E-02	1.121E-01	7.468E-0
70	3.799E+14	-6.190E+00	6.816E+02	-8.133E+00	3.625E-01	1.312E-01	1.982E+0
71	3.485E+15	-5.510E+00	6.734E+02	-6.232E+00	6.958E-02	1.439E-01	2.131E+0
72	1.097E+15	-2.182E+00	8.466E+02	-3.484E+00	1.252E-01	1.235E-01	4.371E+0
73	5.053E+14	-4.906E+00	8.063E+02	-3.782E+00	6.481E-02	1.645E-01	8.575E-0
74	2.672E+14	-2.564E+00	8.374E+02	-4.418E+00	1.040E-01	1.221E-01	1.423E-0
75	2.099E+15	-6.478E+00	8.609E+02	-8.441E+00	4.506E-02	9.805E-02	1.029E+0

LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(21)
1	4.000E+00
2	4.000E+00
3	4.000E+00
4	4.000E+00
5	2.000E+00
6	4.000E+00
7	1.000E+00
8	3.000E+00
9	1.000E+00
10	4.000E+00
11	4.000E+00
12	4.000E+00
13	1.000E+00
14	1.000E+00

15 3.000E+00
16 3.000E+00
17 4.000E+00
18 3.000E+00
19 2.000E+00
20 1.000E+00
21 3.000E+00
22 3.000E+00
23 3.000E+00
24 4.000E+00
25 2.000E+00
26 4.000E+00
27 3.000E+00
28 3.000E+00
29 1.000E+00
30 4.000E+00
31 4.000E+00
32 2.000E+00
33 1.000E+00
34 4.000E+00
35 4.000E+00
36 3.000E+00
37 4.000E+00
38 1.000E+00
39 2.000E+00
40 3.000E+00
41 1.000E+00
42 4.000E+00
43 2.000E+00
44 3.000E+00
45 1.000E+00
46 3.000E+00
47 2.000E+00
48 1.000E+00
49 1.000E+00
50 4.000E+00
51 2.000E+00
52 1.000E+00
53 4.000E+00
54 4.000E+00
55 2.000E+00
56 4.000E+00

57 1.000E+00
 58 4.000E+00
 59 1.000E+00
 60 2.000E+00
 61 1.000E+00
 62 1.000E+00
 63 4.000E+00
 64 3.000E+00
 65 4.000E+00
 66 4.000E+00
 67 2.000E+00
 68 2.000E+00
 69 3.000E+00
 70 1.000E+00
 71 1.000E+00
 72 1.000E+00
 73 1.000E+00
 74 4.000E+00
 75 1.000E+00

RANKS OF LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(1)	X(2)	X(3)	X(4)	X(5)	X(6)	X(7)
1	68.	30.	68.	37.	30.	40.	31
2	39.	32.	42.	50.	30.	41.	67
3	49.	63.	49.	34.	69.	17.	12
4	26.	26.	24.	69.	15.	66.	37
5	30.	31.	28.	31.	30.	61.	3
6	56.	20.	57.	30.	30.	25.	58
7	51.	18.	51.	6.	15.	6.	34
8	52.	24.	52.	33.	30.	20.	22
9	58.	71.	59.	4.	69.	2.	43
10	64.	42.	63.	9.	30.	4.	66
11	63.	2.	64.	25.	5.	14.	7
12	23.	50.	20.	5.	57.	9.	62
13	73.	33.	73.	23.	30.	36.	71
14	19.	54.	21.	41.	69.	24.	14
15	2.	19.	2.	32.	30.	44.	68
16	38.	59.	39.	17.	46.	21.	54
17	70.	57.	70.	15.	69.	39.	46
18	35.	25.	35.	36.	30.	54.	30
19	42.	1.	41.	40.	5.	45.	26
20	74.	73.	74.	71.	69.	57.	8
21	10.	4.	9.	8.	5.	28.	65

22	37.	28.	36.	13.	15.	5.	40
23	44.	44.	44.	73.	30.	74.	63
24	65.	47.	66.	47.	46.	33.	20
25	41.	58.	40.	19.	57.	16.	52
26	48.	12.	48.	39.	15.	23.	75
27	29.	41.	30.	26.	46.	31.	19
28	3.	43.	3.	52.	46.	19.	13
29	43.	53.	43.	7.	69.	42.	15
30	34.	40.	34.	58.	30.	63.	47
31	1.	27.	1.	35.	30.	30.	72
32	8.	29.	8.	72.	15.	73.	49
33	31.	67.	31.	29.	69.	46.	32
34	14.	62.	14.	24.	57.	49.	11
35	6.	55.	7.	46.	57.	38.	45
36	5.	7.	5.	3.	5.	8.	25
37	7.	45.	6.	27.	46.	47.	59
38	4.	37.	4.	11.	30.	7.	2
39	75.	22.	75.	16.	30.	35.	38
40	60.	8.	60.	1.	15.	13.	6
41	18.	72.	16.	12.	69.	22.	51
42	61.	14.	61.	44.	30.	37.	29
43	57.	38.	55.	57.	30.	64.	42
44	12.	35.	13.	55.	30.	26.	48
45	15.	17.	15.	48.	46.	10.	55
46	46.	46.	47.	59.	46.	51.	1
47	20.	13.	19.	22.	15.	3.	16
48	69.	36.	69.	18.	30.	11.	23
49	54.	3.	54.	62.	5.	62.	44
50	11.	15.	11.	38.	15.	27.	4
51	40.	16.	38.	75.	15.	75.	18
52	25.	9.	26.	20.	5.	34.	53
53	36.	74.	37.	21.	69.	32.	60
54	55.	39.	56.	42.	46.	29.	74
55	32.	66.	32.	60.	69.	53.	64
56	17.	10.	18.	43.	15.	52.	27
57	59.	69.	58.	70.	69.	59.	39
58	13.	64.	12.	68.	57.	70.	5
59	45.	34.	45.	64.	46.	50.	69
60	22.	60.	23.	28.	57.	56.	70
61	24.	48.	25.	66.	46.	65.	50
62	33.	56.	33.	56.	46.	60.	73
63	72.	61.	72.	63.	57.	68.	35

64	67.	5.	67.	53.	5.	58.	57
65	9.	68.	10.	49.	57.	43.	10
66	71.	52.	71.	54.	57.	67.	36
67	66.	23.	65.	45.	30.	15.	24
68	21.	21.	22.	74.	30.	72.	61
69	28.	75.	29.	2.	69.	1.	56
70	47.	65.	46.	51.	69.	71.	9
71	16.	51.	17.	65.	57.	48.	33
72	27.	49.	27.	61.	46.	69.	17
73	62.	6.	62.	14.	5.	12.	41
74	50.	70.	50.	10.	69.	18.	21
75	53.	11.	53.	67.	5.	55.	28

RANKS OF LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(11)	X(12)	X(13)	X(14)	X(15)	X(16)	X(1)
1	8.	19.	50.	64.	11.	68.	68
2	9.	26.	24.	49.	44.	35.	6
3	45.	45.	18.	12.	18.	1.	72
4	65.	12.	65.	39.	31.	18.	23
5	25.	18.	9.	35.	61.	4.	27
6	50.	51.	45.	44.	69.	44.	24
7	51.	6.	16.	61.	53.	47.	69
8	42.	71.	38.	65.	42.	29.	10
9	14.	2.	73.	27.	37.	62.	70
10	5.	42.	32.	53.	71.	9.	57
11	67.	66.	29.	74.	64.	43.	55
12	39.	32.	13.	66.	51.	46.	30
13	3.	13.	63.	24.	46.	12.	14
14	4.	62.	55.	19.	1.	40.	12
15	69.	55.	71.	75.	47.	11.	15
16	23.	25.	59.	67.	73.	17.	34
17	62.	38.	68.	52.	2.	75.	20
18	7.	14.	42.	26.	9.	51.	19
19	48.	3.	12.	7.	25.	39.	47
20	12.	27.	14.	55.	30.	3.	1
21	6.	7.	5.	31.	62.	66.	16
22	55.	57.	22.	9.	33.	55.	54
23	34.	64.	40.	10.	70.	21.	26
24	18.	53.	72.	11.	66.	41.	74
25	64.	39.	6.	38.	28.	61.	25
26	21.	35.	64.	13.	26.	26.	41
27	70.	4.	60.	14.	60.	30.	52
28	72.	17.	62.	69.	38.	37.	43

29	35.	36.	74.	43.	54.	15.	29
30	54.	73.	23.	28.	58.	60.	22
31	47.	37.	52.	30.	27.	25.	60
32	44.	33.	30.	21.	32.	57.	40
33	73.	10.	44.	71.	52.	32.	46
34	2.	47.	66.	23.	23.	59.	51
35	40.	52.	3.	63.	14.	24.	32
36	19.	59.	15.	34.	10.	58.	39
37	74.	44.	70.	16.	63.	42.	45
38	43.	68.	36.	8.	39.	63.	66
39	75.	46.	31.	32.	65.	73.	3
40	53.	70.	58.	33.	6.	19.	37
41	16.	29.	2.	72.	13.	36.	64
42	59.	22.	19.	3.	35.	64.	44
43	27.	54.	61.	70.	45.	34.	56
44	29.	60.	10.	37.	40.	53.	13
45	30.	49.	51.	17.	74.	33.	36
46	58.	31.	25.	36.	43.	72.	67
47	20.	9.	11.	59.	48.	10.	18
48	41.	61.	41.	40.	21.	20.	7
49	28.	50.	35.	50.	41.	67.	49
50	17.	20.	67.	57.	8.	8.	5
51	46.	1.	34.	54.	4.	13.	28
52	37.	34.	21.	4.	55.	28.	9
53	56.	40.	28.	1.	57.	50.	11
54	31.	15.	1.	41.	17.	48.	31
55	71.	8.	56.	60.	36.	49.	38
56	1.	58.	54.	45.	68.	6.	61
57	38.	48.	33.	22.	49.	69.	21
58	10.	16.	48.	15.	67.	71.	2
59	11.	24.	43.	47.	5.	56.	65
60	66.	72.	17.	20.	3.	7.	73
61	22.	69.	27.	18.	75.	22.	62
62	13.	67.	39.	62.	7.	45.	59
63	57.	65.	20.	56.	22.	2.	33
64	63.	28.	47.	46.	50.	16.	75
65	15.	23.	26.	68.	72.	74.	50
66	33.	30.	4.	73.	56.	54.	63
67	52.	56.	69.	29.	15.	65.	58
68	24.	41.	75.	58.	16.	70.	35
69	61.	5.	57.	5.	24.	14.	17
70	32.	21.	8.	6.	59.	31.	71

71	68.	43.	7.	25.	20.	38.	53
72	49.	75.	49.	51.	34.	27.	42
73	36.	63.	37.	48.	19.	52.	8
74	26.	74.	46.	42.	29.	23.	4
75	60.	11.	53.	2.	12.	5.	48

RANKS OF LATIN HYPERCUBE SAMPLE INPUT VECTORS

RUN NO.	X(21)
1	63.
2	63.
3	63.
4	63.
5	29.
6	63.
7	12.
8	42.
9	12.
10	63.
11	63.
12	63.
13	12.
14	12.
15	42.
16	42.
17	63.
18	42.
19	29.
20	12.
21	42.
22	42.
23	42.
24	63.
25	29.
26	63.
27	42.
28	42.
29	12.
30	63.
31	63.
32	29.
33	12.
34	63.
35	63.

36	42.
37	63.
38	12.
39	29.
40	42.
41	12.
42	63.
43	29.
44	42.
45	12.
46	42.
47	29.
48	12.
49	12.
50	63.
51	29.
52	12.
53	63.
54	63.
55	29.
56	63.
57	12.
58	63.
59	12.
60	29.
61	12.
62	12.
63	63.
64	42.
65	63.
66	63.
67	29.
68	29.
69	42.
70	12.
71	12.
72	12.
73	12.
74	63.
75	12.

HISTOGRAM FOR VARIABLE NO. 1

UNIFORM

DISTRIBUTION

MIDPOINT	FREQ.	
0.2449999E-01	4	XXXX
0.7349998E-01	4	XXXX
0.1225000	3	XXX
0.1715000	3	XXX
0.2204999	4	XXXX
0.2694999	4	XXXX
0.3184999	3	XXX
0.3674999	4	XXXX
0.4164999	4	XXXX
0.4654999	3	XXX
0.5144999	5	XXXXX
0.5634999	3	XXX
0.6124998	3	XXX
0.6614998	5	XXXXX
0.7104998	3	XXX
0.7594997	4	XXXX
0.8084997	3	XXX
0.8574997	4	XXXX
0.9064996	4	XXXX
0.9554996	4	XXXX
1.004500	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.5195054E-02	0.9939531	0.9887580	0.4991933	0.5005198	0.83

HISTOGRAM FOR VARIABLE NO. 2 NORMAL DISTRIBUTION

MIDPOINT	FREQ.	
-0.3244999E-01	1	X
-0.2654999E-01	2	XX
-0.2064999E-01	1	X
-0.1474999E-01	2	XX
-0.8849997E-02	3	XXX
-0.2950000E-02	5	XXXXX
0.2949998E-02	4	XXXX
0.8849995E-02	7	XXXXXXX
0.1474999E-01	6	XXXXXXX
0.2064999E-01	7	XXXXXXX
0.2654999E-01	6	XXXXXXX
0.3244999E-01	7	XXXXXXX
0.3834999E-01	6	XXXXXXX
0.4424999E-01	4	XXXX

0.5014998E-01	4	XXXX
0.5604998E-01	4	XXXX
0.6194998E-01	2	XX
0.6784998E-01	1	X
0.7374997E-01	1	X
0.7964997E-01	1	X
0.8554997E-01	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-0.3458769E-01	0.8326402E-01	0.1178517	0.2336021E-01	0.2309605E-01	0.64

HISTOGRAM FOR VARIABLE NO. 3 LOGNORMAL DISTRIBUTION

MIDPOINT	FREQ.	
8.50001	66	XX
25.50000	4	XXXX
42.50001	1	X
59.50001	1	X
76.50002	1	X
93.50002	0	
110.5000	0	
127.5000	0	
144.5000	1	X
161.5000	0	
178.5000	0	
195.5000	0	
212.5000	0	
229.5000	0	
246.5000	0	
263.5000	0	
280.5000	0	
297.5000	0	
314.5000	0	
331.5000	0	
348.5000	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.9999980E-03	350.0006	349.9996	11.61960	0.5980396	196

HISTOGRAM FOR VARIABLE NO. 4 UNIFORM DISTRIBUTION

MIDPOINT	FREQ.	
-0.5144998	1	X
-0.4654998	3	XXX

-0.4164998	4	XXXX
-0.3674998	4	XXXX
-0.3184998	4	XXXX
-0.2694998	3	XXX
-0.2204998	4	XXXX
-0.1714998	4	XXXX
-0.1224999	3	XXX
-0.7349989E-01	4	XXXX
-0.2449990E-01	3	XXX
0.2450008E-01	4	XXXX
0.7350007E-01	3	XXX
0.1225001	5	XXXXXX
0.1715000	3	XXX
0.2205000	3	XXX
0.2695000	5	XXXXXX
0.3185000	3	XXX
0.3675000	4	XXXX
0.4165000	3	XXX
0.4655000	5	XXXXXX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-0.4936196	0.4869559	0.9805755	-0.1768669E-05	0.6391935E-02	0.83

HISTOGRAM FOR VARIABLE NO. 5 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
-8.750003	9	XXXXXXXXXX
-6.250002	0	
-3.750002	0	
-1.250001	0	
1.250000	10	XXXXXXXXXX
3.750000	0	
6.250001	0	
8.750002	20	XXXXXXXXXXXXXXXXXXXXXXXXXX
11.25000	0	
13.75000	0	
16.25000	0	
18.75000	0	
21.25000	0	
23.75000	12	XXXXXXXXXXXX
26.25000	0	
28.75000	0	
31.25000	0	

33.75000	10	XXXXXXXXXX
36.25000	0	
38.75000	14	XXXXXXXXXXXXXX
	75	

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-10.00000	40.00000	50.00000	16.88000	8.000000	282

HISTOGRAM FOR VARIABLE NO. 6 UNIFORM DISTRIBUTION

MIDPOINT	FREQ.	
12.00000	1	X
36.00001	4	XXXX
60.00002	5	XXXXX
84.00002	3	XXX
108.0000	3	XXX
132.0000	4	XXXX
156.0000	4	XXXX
180.0000	4	XXXX
204.0000	3	XXX
228.0000	4	XXXX
252.0000	4	XXXX
276.0000	3	XXX
300.0000	4	XXXX
324.0000	4	XXXX
348.0000	3	XXX
372.0000	4	XXXX
396.0000	3	XXX
420.0000	4	XXXX
444.0000	5	XXXXX
468.0000	3	XXX
492.0000	3	XXX
	75	

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
12.92320	497.7050	484.7818	256.1264	254.6725	197

HISTOGRAM FOR VARIABLE NO. 7 LOGUNIFORM DISTRIBUTION

MIDPOINT	FREQ.	
0.2349999E-12	58	XX
0.7049998E-12	5	XXXXX
0.1175000E-11	2	XX
0.1645000E-11	0	
0.2114999E-11	3	XXX
0.2584999E-11	0	

0.3054999E-11	1	X
0.3524999E-11	0	
0.3994999E-11	2	XX
0.4464999E-11	0	
0.4934999E-11	0	
0.5404998E-11	1	X
0.5874998E-11	0	
0.6344998E-11	1	X
0.6814998E-11	0	
0.7284998E-11	0	
0.7754998E-11	0	
0.8224998E-11	1	X
0.8694998E-11	0	
0.9164998E-11	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.1093542E-16	0.9368482E-11	0.9368470E-11	0.7344726E-12	0.9421005E-14	0.32

HISTOGRAM FOR VARIABLE NO. 8 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.
22.00000	1 X
26.00000	6 XXXXXX
30.00000	7 XXXXXXXX
34.00000	7 XXXXXXXX
38.00000	5 XXXXXX
42.00000	4 XXXX
46.00000	3 XXX
50.00000	3 XXX
54.00000	2 XX
58.00000	4 XXXX
62.00000	5 XXXXXX
65.99999	2 XX
69.99999	3 XXX
73.99999	3 XXX
77.99999	2 XX
81.99999	3 XXX
85.99999	5 XXXXXX
89.99999	2 XX
93.99999	3 XXX
97.99999	2 XX
102.0000	3 XXX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
23.21227	102.2718	79.05949	56.98121	54.81532	578

HISTOGRAM FOR VARIABLE NO. 9 NORMAL DISTRIBUTION

MIDPOINT	FREQ.	
-0.4999997E-02	1	X
0.4999997E-02	1	X
0.1499999E-01	0	
0.2499998E-01	2	XX
0.3499998E-01	2	XX
0.4499997E-01	3	XXX
0.5499997E-01	5	XXXXX
0.6499996E-01	4	XXXX
0.7499995E-01	6	XXXXXX
0.8499994E-01	7	XXXXXXXX
0.9499993E-01	7	XXXXXXXX
0.1049999	7	XXXXXXXX
0.1149999	6	XXXXXX
0.1249999	6	XXXXXX
0.1349999	5	XXXXX
0.1449999	3	XXX
0.1549999	4	XXXX
0.1649999	3	XXX
0.1749999	0	
0.1849999	2	XX
0.1949998	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-0.2235174E-07	0.1996517	0.1996517	0.9979033E-01	0.9963441E-01	0.17

HISTOGRAM FOR VARIABLE NO. 10 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
0.4200000E-01	5	XXXXX
0.7000001E-01	0	
0.9800001E-01	6	XXXXXX
0.1260000	0	
0.1540000	5	XXXXX
0.1820000	5	XXXXX
0.2100000	6	XXXXXX
0.2380000	10	XXXXXXXXXX
0.2660000	6	XXXXXX
0.2940000	5	XXXXX

0.3220000	0	
0.3500000	6	XXXXXX
0.3780000	5	XXXXX
0.4060000	0	
0.4340000	5	XXXXX
0.4620000	0	
0.4900000	0	
0.5180000	0	
0.5460000	6	XXXXXX
0.5740000	0	
0.6020000	5	XXXXX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.5080000E-01	0.6096000	0.5588000	0.2950643	0.2794000	0.24

HISTOGRAM FOR VARIABLE NO. 11 LOGUNIFORM DISTRIBUTION

MIDPOINT	FREQ.	
0.1300000E+15	25	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.3900001E+15	12	XXXXXXXXXXXX
0.6500001E+15	6	XXXXXX
0.9100002E+15	5	XXXXX
0.1170000E+16	3	XXX
0.1430000E+16	3	XXX
0.1690000E+16	3	XXX
0.1950000E+16	2	XX
0.2210000E+16	1	X
0.2470000E+16	2	XX
0.2730000E+16	2	XX
0.2990001E+16	2	XX
0.3250001E+16	0	
0.3510001E+16	2	XX
0.3770001E+16	1	X
0.4030001E+16	1	X
0.4290001E+16	1	X
0.4550001E+16	1	X
0.4810002E+16	1	X
0.5070002E+16	0	
0.5330002E+16	2	XX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.5907079E+14	0.5289056E+16	0.5229985E+16	0.1195846E+16	0.5520103E+15	0.19

HISTOGRAM FOR VARIABLE NO. 12 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
-7.700001	3	XXX
-7.420001	0	
-7.140001	2	XX
-6.860001	2	XX
-6.580000	5	XXXXX
-6.300000	9	XXXXXXXXXX
-6.020000	9	XXXXXXXXXX
-5.740000	10	XXXXXXXXXX
-5.460000	10	XXXXXXXXXX
-5.179999	9	XXXXXXXXXX
-4.899999	9	XXXXXXXXXX
-4.619999	1	X
-4.339999	0	
-4.059999	1	X
-3.779999	1	X
-3.499999	1	X
-3.219999	0	
-2.939999	1	X
-2.659999	1	X
-2.379999	0	
-2.099999	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-7.811573	-2.181874	5.629699	-5.605499	-5.657501	1.0

HISTOGRAM FOR VARIABLE NO. 13 NORMAL DISTRIBUTION

MIDPOINT	FREQ.	
586.5001	1	X
609.5001	1	X
632.5001	2	XX
655.5001	2	XX
678.5001	3	XXX
701.5001	4	XXXX
724.5001	4	XXXX
747.5001	6	XXXXXX
770.5001	6	XXXXXX
793.5001	7	XXXXXXX
816.5001	7	XXXXXXX
839.5001	7	XXXXXXX
862.5001	6	XXXXXX

885.5001	5	XXXXX
908.5001	4	XXXX
931.5001	3	XXX
954.5001	2	XX
977.5001	2	XX
1000.500	1	X
1023.500	1	X
1046.500	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
576.9999	1037.569	460.5692	809.2443	808.3821	967

HISTOGRAM FOR VARIABLE NO. 14 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
-8.480000	3	XXX
-8.160000	4	XXXX
-7.840000	4	XXXX
-7.520000	2	XX
-7.199999	4	XXXX
-6.879999	3	XXX
-6.559999	3	XXX
-6.239999	3	XXX
-5.919999	2	XX
-5.599998	4	XXXX
-5.279998	3	XXX
-4.959998	2	XX
-4.639998	4	XXXX
-4.319998	3	XXX
-3.999998	3	XXX
-3.679998	3	XXX
-3.359998	3	XXX
-3.039998	6	XXXXXX
-2.719998	6	XXXXXX
-2.399998	6	XXXXXX
-2.079998	4	XXXX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-8.538051	-2.053085	6.484966	-4.991532	-4.790781	4.1

HISTOGRAM FOR VARIABLE NO. 15 LOGNORMAL DISTRIBUTION

MIDPOINT	FREQ.	
0.5500000E-01	30	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

0.1650000	18	XXXXXXXXXXXXXXXXXXXX
0.2750000	9	XXXXXXXXXX
0.3850000	5	XXXXX
0.4949999	4	XXXX
0.6050000	2	XX
0.7150000	1	X
0.8250000	1	X
0.9350000	2	XX
1.045000	0	
1.155000	0	
1.265000	1	X
1.375000	0	
1.485000	0	
1.595000	0	
1.705000	1	X
1.815000	0	
1.925000	0	
2.035000	0	
2.145000	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.9999994E-02	2.130001	2.120001	0.2732225	0.1482280	0.13

HISTOGRAM FOR VARIABLE NO. 16 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
0.6239996E-01	1	X
0.7199995E-01	1	X
0.8159994E-01	0	
0.9119993E-01	2	XX
0.1007999	6	XXXXXX
0.1103999	5	XXXXX
0.1199999	12	XXXXXXXXXXXX
0.1295999	5	XXXXX
0.1391999	6	XXXXXX
0.1487999	5	XXXXX
0.1583999	8	XXXXXXXX
0.1679999	4	XXXX
0.1775999	9	XXXXXXXXXX
0.1871999	2	XX
0.1967999	1	X
0.2063999	5	XXXXX
0.2159999	1	X

25.29999	2	XX
29.89999	5	XXXXXX
34.49999	3	XXX
39.09999	3	XXX
43.69999	3	XXX
48.29998	7	XXXXXXXX
52.89998	3	XXX
57.49998	3	XXX
62.09998	2	XX
66.69998	2	XX
71.29998	3	XXX
75.89998	3	XXX
80.49998	2	XX
85.09998	1	X
89.69997	5	XXXXXX
94.29997	3	XXX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
1.497821	94.20219	92.70438	42.20030	40.65907	796

HISTOGRAM FOR VARIABLE NO. 19 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
-12.39500	1	X
-12.02500	1	X
-11.65500	2	XX
-11.28500	1	X
-10.91500	1	X
-10.54500	1	X
-10.17500	1	X
-9.804998	2	XX
-9.434999	0	
-9.064999	3	XXX
-8.694999	5	XXXXXX
-8.324999	5	XXXXXX
-7.954999	5	XXXXXX
-7.584999	5	XXXXXX
-7.214999	5	XXXXXX
-6.844999	5	XXXXXX
-6.474999	6	XXXXXXX
-6.105000	8	XXXXXXXXXX
-5.735000	7	XXXXXXXXXX
-5.365000	8	XXXXXXXXXX

-4.995000 3 XXX

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
-12.46164	-5.037228	7.424414	-7.410848	-7.086456	3.3

HISTOGRAM FOR VARIABLE NO. 20 LOGUNIFORM DISTRIBUTION

MIDPOINT	FREQ.	
20.99999	63	XX
62.99998	3	XXX
105.0000	1	X
147.0000	2	XX
189.0000	0	
230.9999	1	X
272.9999	0	
314.9999	1	X
356.9999	0	
398.9999	1	X
440.9999	0	
482.9999	0	
524.9999	1	X
566.9999	0	
608.9999	0	
650.9999	0	
692.9999	0	
734.9999	1	X
776.9999	0	
818.9999	1	X

75

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
0.1257535E-05	831.6160	831.6160	50.22662	0.3609625E-01	227

HISTOGRAM FOR VARIABLE NO. 21 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.	
0.9750000	22	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
1.125000	0	
1.275000	0	
1.425000	0	
1.575000	0	
1.725000	0	
1.875000	0	
2.025000	12	XXXXXXXXXXXX
2.175000	0	

```

2.325000      0
2.475000      0
2.625000      0
2.775000      0
2.925000     15  XXXXXXXXXXXXXXXXXXXX
3.075001      0
3.225001      0
3.375001      0
3.525001      0
3.675001      0
3.825001      0
3.975001     26  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
75

```

MIN	MAX	RANGE	MEAN	MEDIAN	VAR
1.000000	4.000000	3.000000	2.600000	3.000000	1.5

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RAW

```

1  1.0000
2 -0.0403  1.0000
3  0.4040  0.0240  1.0000
4 -0.0224  0.0076 -0.0472  1.0000
5 -0.0455  0.9149  0.0086  0.0090  1.0000
6 -0.0094  0.0745  0.0407  0.7775  0.0637  1.0000
7 -0.0030 -0.0488 -0.0399  0.0228 -0.0460 -0.0159  1.0000
8  0.0058  0.0314 -0.0657  0.0360 -0.0070 -0.0127  0.4476  1.0000
9  0.0069 -0.0070  0.0810 -0.0041 -0.0077 -0.0440  0.4065  0.5927  1.0000
10 -0.0265 -0.0214  0.0014 -0.0086  0.0157 -0.0777  0.0020  0.0704 -0.0026  1.
11 -0.0396  0.0298  0.2601 -0.0427  0.0859  0.0207 -0.1112  0.0403  0.0121 -0.
12  0.0035  0.0403 -0.0047  0.0187  0.0332  0.0371 -0.0081 -0.0152 -0.0059 -0.
13  0.0361 -0.0120 -0.0470 -0.0042 -0.0177  0.0186 -0.0206  0.0034 -0.0337 -0.
14  0.0741 -0.0204  0.0471  0.0252  0.0211  0.0207 -0.0227 -0.0411 -0.0135 -0.
15 -0.0975  0.0152  0.0194  0.0671  0.0315  0.0242 -0.1200  0.0756  0.1001 -0.
16  0.0083 -0.0096  0.1121  0.0054  0.0280  0.0158 -0.0940 -0.0285  0.0155  0.
17  0.1953 -0.1377  0.0104  0.0824 -0.1337  0.0964 -0.0244  0.0390  0.0932 -0.
18  0.0154 -0.0157  0.0183 -0.0047  0.0450 -0.0391  0.0658  0.0276  0.0511  0.
19  0.0091  0.0204  0.0001  0.0440  0.0904  0.0339 -0.0092 -0.0485  0.0141  0.
20  0.0831  0.0508 -0.0404 -0.0592  0.0199 -0.0482 -0.0735 -0.0114  0.0697  0.
21 -0.0408 -0.0115 -0.0897 -0.0744 -0.0171 -0.0692  0.1020 -0.0387  0.0242  0.
      1      2      3      4      5      6      7      8      9

```

VARIABLES

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RAW

```

16  1.0000
17 -0.1202  1.0000

```

18	0.0070	0.2074	1.0000			
19	0.0287	-0.0253	0.0563	1.0000		
20	0.0666	0.0497	-0.0531	-0.0974	1.0000	
21	0.0432	0.0670	-0.0219	-0.0343	0.0951	1.0000
	16	17	18	19	20	21

VARIABLES

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RANK

1	1.0000									
2	-0.0330	1.0000								
3	0.9990	-0.0300	1.0000							
4	-0.0212	0.0265	-0.0190	1.0000						
5	-0.0128	0.9352	-0.0080	0.0003	1.0000					
6	-0.0075	0.1110	-0.0110	0.7785	0.0583	1.0000				
7	-0.0305	-0.0233	-0.0269	-0.0141	-0.0349	0.0150	1.0000			
8	-0.0094	0.0119	-0.0075	0.0164	-0.0140	-0.0195	0.5857	1.0000		
9	0.0257	0.0081	0.0263	-0.0108	0.0073	-0.0449	0.5976	0.5861	1.0000	
10	-0.0270	-0.0214	-0.0287	-0.0033	-0.0156	-0.0481	-0.0338	0.0273	0.0003	1.
11	0.0374	-0.0195	0.0348	-0.0072	0.0200	0.0012	0.0026	0.0475	0.0151	0.
12	0.0193	0.0008	0.0272	0.0008	-0.0107	-0.0264	-0.0037	0.0228	0.0154	-0.
13	0.0262	-0.0368	0.0312	-0.0038	0.0087	0.0072	-0.0003	0.0418	-0.0031	-0.
14	0.0539	0.0170	0.0487	0.0165	0.0262	0.0105	0.0190	-0.0316	-0.0072	-0.
15	-0.0229	0.0152	-0.0222	-0.0282	-0.0194	0.0372	0.0333	-0.0026	0.0161	0.
16	-0.0012	0.0158	0.0005	0.0128	0.0440	-0.0166	0.0230	0.0040	-0.0376	0.
17	0.0368	0.0388	0.0358	0.0733	0.0320	0.0609	-0.0328	0.0366	-0.0205	-0.
18	0.0091	0.0424	0.0107	-0.0183	0.0646	-0.0438	-0.0078	0.0077	0.0323	0.
19	0.0547	0.0028	0.0530	0.0238	0.0831	0.0108	-0.0502	-0.0434	-0.0525	0.
20	0.0249	-0.0349	0.0207	0.0031	-0.0424	-0.0593	0.0245	0.0504	0.0290	-0.
21	-0.0328	-0.0015	-0.0295	-0.0640	-0.0234	-0.0599	0.0431	-0.0150	0.0229	0.
	1	2	3	4	5	6	7	8	9	

VARIABLES

CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RANK

16	1.0000					
17	0.0657	1.0000				
18	0.0173	0.0235	1.0000			
19	0.0619	0.0031	0.0472	1.0000		
20	0.0002	-0.0273	-0.0001	0.0127	1.0000	
21	0.0364	-0.0580	-0.0424	-0.0527	0.0112	1.0000
	16	17	18	19	20	21

VARIABLES

OUTPUT FILE FOR LHS TEST 5

THE PARAMETER CARD NOBS CONTAINS THE NON-NUMERIC CHARACTER T

FORTRAN-like assignment statements and general-purpose commands.

ALGEBRACDB's capabilities used in the CCA PA calculations have been tested. All the capabilities mentioned in this section are tested unless otherwise noted. Properties, attributes, and time step variables can be created, modified, or deleted. The manipulations can be limited to a specified set of nodes or elements or elements blocks.

The user can create or modify the CAMDAT entities based on the values of existing properties, attributes, time step variables, nodal coordinates, time step time, and numeric constants. Certain constants referring to the input CAMDAT file (such as the number of nodes or elements) can also be used. The nodes and elements and element blocks over which operations on the input data are valid can be limited. A value for a specific node or element or element block can be referenced. The values of the first time step or the previous time step can also be referenced.

The following manipulations can be applied to the input data to derive the output data. The manipulations apply to each node or element or element block, if appropriate.

- Addition, subtraction, multiplication, division, and exponentiation.
- Standard FORTRAN functions: AINT, ANINT, ABS, MOD, SIGN, DIM, MIN, MAX, SQRT, EXP, LOG, LOG10, SIN, COS, TAN, ASIN, ACOS, ATAN, ATAN2, SINH, COSH, TANH.
- Integration using the trapezoidal rule or the rectangular rule.
- Conditional assignment (a limited IF-THEN-ELSE capability).
- Addition of the values for all nodes or elements or blocks.
- Minimum or maximum value over all nodes or elements or blocks at each time step.
- Minimum or maximum value over all time steps.
- Location of the minimum and maximum value over all nodes or elements and over all time steps. The node or element number and time step number is also retained.
- Conversion from a nodal variable to an element variable and vice versa.

- Assignment to a compatible data type. For example, a constant can be explicitly assigned to a global variable.

The manipulations can be limited to certain time steps. These time steps are the only ones processed and the only ones written to the output CAMDAT file. The CAMDAT title and information records can be changed. Information about the CAMDAT file can be listed to the output diagnostics file. This is particularly useful if the user is entering instructions interactively.

ALGEBRACDB can accept up to 2,000 assignment statements. There is also a limit on the number of total syntactic entities in all assignment statements (20,000). Each input control file line is limited to 80 characters. These lines may be concatenated, but each assignment statement and command is limited to 256 characters. There is a limit of 2,500 variables. This includes all properties, attributes, and time step variables that are on the input CAMDAT file or are assigned by ALGEBRACDB. There is a limit of 1,000 LIMIT commands. There is a limit of 4,000 ranges specified in all LIMIT statements.

The Input CAMDAT File

The input CAMDAT file is a binary, sequential file. A detailed description of the CAMDAT file format is given in Chapter 7 of the WIPP PA User's Manual for CAMDAT__LIB, Version 1.22 (WPO #27727). The information that is relevant to ALGEBRACDB is summarized below.

A CAMDAT file may be referred to as a *CDB* or a *CAMDAT database*, but it is not a database in the traditional use of the word. The CAMDAT file may be examined with the GROPECDB program described in the WIPP PA User's Manual for GROPECDB Version 2.12 (WPO #37496).

The CAMDAT file deals with three finite-element entities: nodes, elements, and element blocks. It is important to understand what each of these entities represents and how they are referenced. A finite-difference grid may also be represented in the CAMDAT file; the grid is mapped to the equivalent finite-element mesh.

- A *node* is a specific grid point. Nodes are referenced by their number, which is determined by the order in which the coordinates are listed in the CAMDAT file.
- An *element* is a grid block formed by connecting adjacent nodes. Elements are referenced by their number, which is determined by the order in which

the connectivity is listed in the CAMDAT file.

- Element data are stored in *element* blocks. In WIPP PA, each element block consists of a group of elements representing a different type of material or a layer of strata surrounding the repository. Each element in a particular block has the same material and element type. Element blocks are referenced by a unique integer identifier, but they also have an associated eight-character name.

Four types of information are stored in a CAMDAT file:

- Initialization information (such as the CAMDAT version and sizing information).
- Quality assurance information.
- Model description data, such as finite-element or finite-difference geometry data; geologic, hydrologic, and chemical parameters; and model boundary conditions.
- Analysis results data, such as head, pressure, velocity components, concentrations from source term or transport modules, and particle transport pathways.

Descriptions of each of these types of information follows.

Initialization Information

The *sizes of all QA and model description information* (such as the number of nodes and elements) are stored in the CAMDAT file. These sizes include the number of QA records and information records, the number of dimensions, nodes, elements, and element blocks, the number of unique attributes and properties, and the length of the boundary condition arrays.

Quality Assurance Information

The *database title* is an 80-character string describing the data file.

There should be one *QA record* for each code that writes to the file. Each QA record contains the program name (truncated to eight characters), the program version, and the execution date and time of the program.

An *information record* is an 80-character string. A CAMDAT file can contain any number of information records. The contents of the first three information records

are defined by WIPP PA convention.

Model Description

The *nodal coordinates* of each node in the mesh are stored in the CAMDAT file, along with a label for each dimension.

The *connectivity* for an element is the numbers of each node that must be connected together to form each element. All elements in an element block must be of the same element type (i.e., contain the same number of nodes).

Element block *properties* are material parameters that are constant for a block (e.g., rock density, nuclide partition coefficients) or do not vary at all. Each property has a name for identification. A particular property need not be defined in all element blocks.

Although some properties are stored as element block information, many are stored as element *attributes* to accommodate subtle changes of parameters within the same stratigraphic layer, if necessary. An attribute can vary with each element (e.g., transmissivity, porosity, brine density). Each attribute has a name for identification. A particular attribute need not be defined in all element blocks.

The CAMDAT file can store boundary condition information (e.g., load or fluid pressure conditions) either as a *node set* or an *element side set*. A node set consists of a set of nodes and their associated factors. A side set consists of a set of element sides, the nodes which define the side, and a factor associated with each element side.

Analysis Results

The analysis results comprise the final section of the CAMDAT file. This section contains analysis results for any number of *time steps*. Time steps are identified by the associated time or time step number. There are four types of variables:

- A *History Variable* has a single value for each time step. These values often apply to the large regions or the entire analysis, such as total energy or mass of the system.
A history variable may also represent a value for a specific node or element.
- A *Global Variable* has a single value for each time step that includes the values of nodal and element variables. The difference between history variables and global variables is how often the variables are output on the

CAMDAT file as discussed below.

- A *Nodal Variable* has a value for each node in the mesh for each time step that contains nodal and element variables.
- An *Element Variable* has a value for each element in the mesh (typically) for each time step that contains nodal and element variables. An element variable may not be defined in the CAMDAT file for every element block, but most codes used in the WIPP PA define each element variable for all element blocks.

Each variable has an eight-character identifying name.

There are two different types of time steps. A *whole time step* contains the values of all the variables of all four types (history, global, nodal, and element). A *history-only time step*, contains only the history variables. The use of this type of time step allows the analyst to reduce the size of the output file. For example, the program may calculate flow through all elements at intervals and write this information as an element variable. The program may also need to integrate the flow across a boundary. The integration may need more data points than the element variable intervals so the flow across specific boundary locations would be output at more frequent intervals as history variables.

EPA REVIEW

a) Any compliance application shall include:

a.1) A description of conceptual models and scenario construction used to support any compliance application.

ALGEBRACDB only manipulates a CAMDAT database file. Conceptual models and scenario construction are not applicable to ALGEBRACDB

a.2) A description of plausible alternative conceptual model(s) seriously considered but not used to support such application, and an explanation of the reason(s) why such model(s) was not deemed to accurately portray performance of the disposal system.

ALGEBRACDB only manipulates a CAMDAT database file. Conceptual models and scenario construction are not applicable to ALGEBRACDB.

a.3) Documentation that:

a.3.i) conceptual models and scenarios reasonably represent possible future states

of the disposal system;

ALGEBRACDB only manipulates a CAMDAT database file. Conceptual models and scenario construction are not applicable to ALGEBRACDB

a.3.ii) mathematical models incorporate equations and boundary conditions which reasonably represent the mathematical formulation of the conceptual models;

ALGEBRACDB only manipulates a CAMDAT database file. Conceptual models and scenario construction are not applicable to ALGEBRACDB

a.3.iii.) numerical models provide numerical schemes which enable the mathematical models to obtain stable solutions;

ALGEBRACDB only manipulates a CAMDAT database file. Conceptual models and scenario construction are not applicable to ALGEBRACDB

a.3.iv) computer models accurately implement the numerical models; i.e., computer codes are free of coding errors and produce stable solutions;

Testing of the ALGEBRACDB indicates that it is free from coding errors.

a.3.v) Conceptual models have under gone peer review according to §194.27.

Peer review is not applicable to this code.

b) Computer codes used to support any compliance application shall be documented in a manner that complies with ASME NQA-2a-1990 addenda, part 2.7, to ASME NQA-2-1989 edition.

Quality assurance documents including the User's Manual, the Requirements Document & Verification and Validation Plan, the Validation Document, and Implementation Document are the QA Packages for 13 PA Codes provided by DOE (Docket: A-93-02, II-G-3, Volume 1). This documentation indicates that the ASME NQA requirements have been met. The functional requirements for ALGEBRACDB are complete and cover the usage of the code in the CCA PA calculations.

c) Documentation of all models and computer codes are included in the CCA. Documentation includes the following (To answer may of these question you may be able to reference section b above):

c.1.) Description of the theoretical backgrounds of each model and the method of analysis or assessment,

The User's Manual (UM) adequately describes the theoretical background of the ALGEBRACDB computer code.

c.2.) General descriptions of the models;

discussions of the limits of the applicability of each model;

The describes the limits of applicability of the ALGEBRACDB computer code. These limits are listed in the introduction to Appendix A7 of this TSD.

detailed instruction for executing the computer codes, including hardware and software requirements, Input and output formats with explanations of each input and output variable and parameter;

Adequate instructions are provided in the UM to execute the ALGEBRACDB computer code and an adequate description of input and output files are also provided.

listings of input and output files from a sample computer run; and

These are adequately provided in the ALGEBRACDB UM.

reports on code verification, bench marking, validation, and QA procedures. (QA documents may help)

These are adequately provide in the RD/VVP and the VD for the ALGEBRACDB computer code.

c.3.) Detailed description of the structure of computer codes and complete listings of the source codes;

A complete listing of the source for ALGEBRACDB is provide in the Implementation Document.

c.4.) Detailed descriptions of data collection procedures, sources of data, data reduction and analysis, and code input parameter development; Which parameters appear to be important to compliance?

This does not apply to the ALGEBRACDB computer code because its input parameters are derived from other CCA PA computer codes.

c.5.) Necessary licenses; and

No licenses were required for ALGEBRACDB .

c.6.) An explanation of the manner in which models and computer codes

incorporate the effects of parameter correlation.

Parameter correlation is not an issue in ALGEBRACDB.

d) The Administrator or the Administrator's authorized representative may verify the results of computer simulations used to support any compliance application by performing independent simulations. Data files, source codes, executable versions of computer software for each model, other material or information needed to permit the Administrator or the Administrator's authorized representative to perform independent simulations, and access to necessary hardware to perform such simulation, shall be provided within 30 calendar days of a request by the Administrator or the Administrator's authorized representative.

DOE identified appropriate contacts and provided the documentation required by EPA for its review of this code.

Results for Examination of the 10 Test Cases of ALGEBRA

There were 10 test cases to examine 18 functional requirements, 5 external interfaces and 8 additional functionalities which made up the purpose of the ALGEBRA code. There were six main functions for ALGEBRA: Sum, Integrate, Envelope, If, Limit and 21 trigonometric functions (AINT, ANINT, ABS, MOD, DIM, MAX, MIN, SQRT, EXP, LOG, LOG10, SIN, COS, TAN, ASIN, ACOS, ATAN, ATAN2, SINH, COSH, TANH).

Each of the functional requirements was tested once in the 10 test cases. In general, this "one time testing" is sufficient for proper evaluation of the functional requirements. However, if the results of the 10 test cases produced an error, then additional testing would be necessary. This did not occur with any of the ALGEBRA test cases. The test done by DOE on the ALGEBRACDB computer code show that the code is adequate for use in the CCA PA calculations.

APPENDIX A8 STEPWISE AND PCCSRC COMPUTER CODE EVALUATION

The STEPWISE and PCCSRC computer codes provide the tools to perform sensitivity analysis to determine the important contributors to WIPP performance uncertainty. A Monte Carlo conceptual framework for uncertainty and sensitivity analysis is explained in DOE 1995a, DOE 1995e, Helton 1993, Helton 1994, and Docket: A-93-02, II-G-07. Uncertainty is defined in terms of stochastic and

subjective components. Stochastic uncertainty comes from the different ways that the WIPP disposal system can perform and leads to a complementary cumulative distribution function (CCDF) for the cumulative release. Subjective uncertainty comes from lack of knowledge of the analysts determining performance and leads to a distribution of CCDF's.

Sometimes it is not clear whether an uncertainty is stochastic or subjective. In Section 6.1.4 of the CCA (Docket: A-93-02, II-G-1, Volume I, Chapter 6), it is stated that "For the WIPP, the DOE treats uncertainty associated with significant future human actions as stochastic (for example, drilling for natural resources), and uncertainty in disposal system properties that are subject to ongoing physical processes as subjective (for example, climate change or gas generation)". Scenarios are defined in order to provide a practical way to describe future performance of the disposal system. Scenarios are subsets of similar possible future occurrences that encompass all events considered in determining performance uncertainty.

An individual CCDF is computed from a statistical description of the different ways that the disposal system can perform using the method of importance sampling. The distribution of CCDF's is computed from a statistical description of analyst uncertainty using the Latin hypercube sample (LHS) method.

STEPWISE/PCCSRC determines the sensitivity of the distribution of CCDF's and intermediate variables to input parameters as explained in References DOE 1995a, DOE 1995e, Helton 1993, and Helton 1994. Scatter plot, regression, and correlation methods are used. The sensitivity methods use the same values for the variables of interest and input parameters that are obtained from application of the LHS method.

Scatter plots of variables of interest versus individual input parameters provide qualitative sensitivity information about nonlinear relationships. Quantitative sensitivities are provided by standardized regression coefficients (SRC's) that relate variables of interest to input parameters. The coefficients are standardized relative to the sample variation in the input parameters. If a standardized coefficient for one parameter is twice the size of a standardized coefficient for another parameter, then the variable of interest really is twice as sensitive to the first as it is to the second.

Quantitative sensitivities are also provided by partial correlation coefficients (PCC's) that determine the correlations of the variables of interest to the input

parameters. The partial correlation is computed between the parts of the variable of interest and the input parameter that have been corrected to remove terms that are correlated with other more highly correlated input parameters. PCC's are particularly convenient to quantify sensitivities for variables of interest that are functions of space or time.

SRC's are obtained using stepwise regression to relate variables of interest to input parameters based on the sample values from the LHS method used to determine the distribution of CCDF's. Stepwise regression performs a step-by-step procedure to select the subset of input parameters that best explains the variability in the variable of interest. The regression can be performed by including and eliminating input parameters in each step, only eliminating input parameters through backward steps, or only including parameters through forward steps. Regression sensitivities to nonlinear functions of input parameters can be determined where the form of the nonlinear function may be suggested by the qualitative information from scatter plots.

For nonlinear situations, both regression and partial correlation can be performed on input parameter ranks rather than on the parameter values. The parameter sample values are replaced by the parameter rank that is one for the smallest sample, two for the next smallest, and so forth. Regression produces standardized rank regression coefficients (SRRC's) and correlation analysis produces partial rank correlation coefficients (PRCC's).

EPA REVIEW

a) Any compliance application shall include:

a.1) A description of the conceptual models and scenario construction used to support any compliance application.

Since the purpose of these codes is to perform sensitivity analyses, descriptions of scenario construction and conceptual models is not applicable.

a.2) A description of plausible alternative conceptual model(s) seriously considered but not used, and an explanation of the reason(s) why such model(s) was not deemed to accurately portray performance of the disposal system.

The summary of WIPP results in Docket: A-93-02, II-G-07 refers to Helton 1993 for explanation of the uncertainty and sensitivity methods. Helton 1993 considers the alternative formulations of differential analysis, response surface methodology,

and Fourier amplitude sensitivity test. It is concluded that the Monte Carlo method is the most widely applicable to problems that arise in performance assessment for radioactive waste disposal.

Differential analysis is inherently local, and it is difficult to implement the derivatives required by the method. Response surface methodology requires a simple response surface approximation to the original model, but this is difficult for the complex models that are appropriate for the WIPP disposal system. The Fourier method is highly specialized and difficult to implement. The Monte Carlo method accounts directly for nonlinear relationships, only requires multiple model evaluations to implement, does not require special simplifications of the original model, and is amenable to sensitivity analysis using stepwise regression and partial correlation methods.

a.3) Documentation that:

a.3.i) Conceptual models and scenarios reasonably represent possible future states of the disposal system,

As explained in References DOE 1995a and DOE 1995e, the STEPWISE/PCCSRC codes determine the sensitivity of variables computed by other WIPP codes to input parameters. The other WIPP codes model physical phenomena and scenarios so a reasonable representation of possible future states is dependent on these other codes.

a.3.ii) mathematical models incorporate equations and boundary conditions which reasonably represent the mathematical formulation of the conceptual models,

References DOE 1995a and DOE 1995e describe regression and partial correlation equations for representing model sensitivities. The representations include nonlinear transformations on the input variables and the use of parameter rank instead of the parameter values. These are appropriate equations for the wide variety of sensitivity analyses needed for a system of the complexity of the WIPP.

a.3.iii) numerical models provide numerical schemes which enable the mathematical models to obtain stable solutions

References DOE 1995a, DOE 1995f, Docket: A-93-02, II-G-07, Helton 1993, and Helton 1994 describe well known numerical methods for stepwise regression and partial correlation analysis. The behavior of these methods has been understood for many years in statistical communities. It has been well established that these

methods produce stable solutions.

a.3.iv) computer models accurately implement the numerical models; i.e., computer codes are free of coding errors and produce stable solutions,

The Validation Documents (DOE 1996b and 1995f) show that the codes have been adequately tested for errors.

a.3.v) conceptual models have undergone peer review according to §194.27.

STEPWISE/PCCSRC provide sensitivities of other WIPP codes that are based on conceptual models that have undergone peer review as described in Docket: A-93-02, II-G-1, Volume XII, Appendix PEER, PEER 1).

b) Computer codes used to support any compliance application shall be documented in a manner that complies with ASME NQA-2a-1990 addenda, part 2.7, to ASME NQA-2-1989 edition.

The User's Manuals of References DOE 1995a and 1995e are complete and provide the kind of information needed to understand and run the codes. Functional requirements for STEPWISE and PCCSRC are contained in these User's Manuals and in the Requirements Documents of References DOE 1996a, DOE 1995b, and DOE 1996c. The requirements are complete and adequate for use of the codes in the WIPP PA. STEPWISE is required to perform several types of stepwise regression for the input parameters, specified nonlinear functions of the input parameters, and ranks of the input parameters. STEPWISE is also required to produce scatter plots. PCCSRC is required to compute partial correlation coefficients (PCC's) and SRC's for the input parameters, specified nonlinear functions of the input parameters, and ranks of the input parameters.

Testing for STEPWISE and PCCSRC is described in References DOE 1996a, DOE 1995b, DOE 1996b, DOE 1995c, DOE 1996c, and DOE 1995f. Statistical results were tested by comparing with the Statistical Analysis System (SAS) software.

Originally three functional tests were performed for STEPWISE and the acceptance criteria were met. These tests verified stepwise regression on raw and ranked data, forcing an independent variable into the regression, dropping an observation, backward and forward stepping, transformations on input variables, and plotting features. However, two errors were later discovered so two additional test were performed.

In Version 2.20 of STEPWISE when a variable was dropped from the regression,

the R^2 value used to make decisions about dropping variables was incorrectly assigned to the next variable. This problem was fixed in Version 2.21. An additional test was performed to verify that decisions about dropping or including variables are made correctly. Also, an intermittent plotting error was fixed, and an additional test was performed for verification.

Four functional tests were performed for PCCSRC and the acceptance criteria were met. Partial Correlation Coefficients (PCC's) and Standardized Regression Coefficients (SRC's) were calculated on raw and ranked data sets, transformations on input variables were performed, and data sets were used which span multiple step intervals.

The Implementation Documents of References DOE 1995d and DOE 1995g provide adequate detail on the source codes for STEPWISE and PCCSRC.

c) Documentation of all models and computer codes included as part of any compliance application performance calculation shall be provided. Such documentation shall include, but shall not be limited to:

c.1) Description of the theoretical backgrounds of each model and the method of analysis or assessment,

References DOE 1995a, DOE 1995e, Helton 1993, and Docket: A-93-02, II-G-07 provide detailed descriptions of the theoretical background for STEPWISE/PCCSRC. The documentation explains how the empirical methods of STEPWISE/PCCSRC are used to obtain the sensitivities of performance uncertainties computed in a Monte Carlo framework. Alternative methods such as differential analysis are considered. However, DOE explains that these alternative empirical methods are not as well suited to the complex nature of the physical and statistical models for the disposal system.

c.2) General descriptions of the models; discussions of the limits of applicability of each model; detailed instructions for executing the computer codes, including hardware and software requirements, input and output formats with explanations of each input and output variable and parameter (e.g., parameter name and units); listing of input files from a sample computer run; and reports on code verification, benchmarking, validation, and quality assurance procedures;

Complete descriptions of the empirical regression and correlation models used by STEPWISE/PCCSRC are contained in References DOE 1995a and DOE 1995e.

c.3) Detailed description of the structure of computer codes and complete listings of the source codes;

Complete Implementation Documents are provided in References DOE 1995d and DOE 1995g. These documents provide a full listing of the source codes.

c.4) Detailed descriptions of data collection procedures, sources of data, data reduction and analysis, and code input parameter development

As explained in References DOE 1995a and DOE 1995e, STEPWISE/PCCSRC use regression and correlation methods to determine sensitivities of performance uncertainties to input parameters. The inputs to STEPWISE/PCCSRC are the values for variables of interest and input parameters computed as output of the Latin hypercube sampling (LHS) used to compute disposal system uncertainties.

c.5) Any necessary licenses

No licenses are required.

c.6) An explanation of the manner in which models and computer codes incorporate the effects of parameter correlation

As explained in Appendix PAR, Section PAR.4 (Docket: A-93-02, II-G-1, Volume XI) and in Helton 1993, parameter correlation is incorporated in the LHS method for determining disposal system uncertainty. STEPWISE/PCCSRC use the LHS results to determine the sensitivities of the uncertainty.

d) The Administrator or the Administrator's authorized representative may verify the results of computer simulations used to support any compliance application by performing independent simulations. Data files, source codes, executable versions of computer software for each model, other material or information needed to permit the Administrator or the Administrator's authorized representative to perform independent simulations, and access to necessary hardware to perform such simulation, shall be provided within 30 calendar days of a request by the Administrator or the Administrator's authorized representative.

DOE identified appropriate contacts and provided the documentation required by EPA for its review of these codes.

REFERENCES

DOE (U.S. Department of Energy) 1995a. WIPP PA User's Manual for

STEPWISE (Version 2.20) Document Version 1.00 WPO # 27768, November 1, 1995.

DOE (U.S. Department of Energy) 1996a. WIPP PA Requirements Document & Verification and Validation Plan for STEPWISE (Version 2.21) Document Version 1.01, WPO # 42250, November 21, 1996.

DOE (U.S. Department of Energy) 1995b. WIPP PA Requirements Document & Verification and Validation Plan for STEPWISE (Version 2.20) Document Version 1.00, WPO # 27767, November 1, 1995.

DOE (U.S. Department of Energy) 1996b. WIPP PA Validation Document for STEPWISE (Version 2.21) Document Version 1.01, WPO # 42252, November 21, 1996.

DOE (U.S. Department of Energy) 1995c. WIPP PA Validation Document for STEPWISE (Version 2.20) Document Version 1.00, WPO # 27770, November 11, 1995.

DOE (U.S. Department of Energy) 1995d. WIPP PA Implementation Document for STEPWISE (Version 2.20) Document Version 1.0, WPO # 27769, December, 1995.

DOE (U.S. Department of Energy) 1995e. WIPP PA User's Manual for PCCSRC (Version 2.21) Document Version 1.0 WPO # 27773, November 1, 1995.

DOE (U.S. Department of Energy) 1996c. WIPP PA Requirements Document & Verification and Validation Plan for PCCSRC (Version 2.21) Document Version 1.00, WPO # 27772, June 3, 1996.

DOE (U.S. Department of Energy) 1995f. WIPP PA Validation Document for PCCSRC (Version 2.21) Document Version 1.00, WPO # 27775, November 1, 1995.

DOE (U.S. Department of Energy) 1995g. WIPP PA Implementation Document for PCCSRC (Version 2.21) Document Version 1.0, WPO # 27774, November 11, 1995.

Helton, J., 1993. "Uncertainty and Sensitivity Analysis Techniques for Use in Performance Assessment for Radioactive Waste Disposal", *Reliability Engineering and System Safety*, Vol. 42, pp. 327-367.

Helton, J., 1994. "Treatment of Uncertainty in Performance Assessments for

Complex Systems”, *Risk Analysis*, Vol.14, No.4.

See Appendix B(14) for listing of docketed references.

Intro

Endnotes

1 (Popup - Popup)

Peer Review is discussed in [Section 7](#) of this TSD.

2 (Popup - Appendix B - Not available)

Appendix B of the Technical Support Document is not available electronically.

3 (Popup - Appendix B - Not available)

Appendix B of the Technical Support Document is not available electronically.

4 (Popup - Appendix B - Not available)

Appendix B of the Technical Support Document is not available electronically.

5 (Popup - Popup)

Final versions of these draft reports are filed in Category V-B:

V-B-12 [Technical Support Document for Section 194.23: Parameter Report](#)

V-B-13 [Technical Support Document for Section 194.23: Sensitivity Analysis Report](#)

V-B-14 [Technical Support Document for Section 194.23: Parameter Justification Report](#)

6 (Popup - Popup)

This section appears to be missing from the final document.

7 (Popup - Popup)

This section appears to be missing from the final document.

8 (Popup - Popup)

This section appears to be missing from the final document.

9 (Popup - Popup)

This section appears to be missing from the final document.

10 (Popup - Popup)

This section appears to be missing from the final document.

11 (Popup - Popup)

This section appears to be missing from the final document.

12 (Popup - Popup)

This section appears to be missing from the final document.

13 (Popup - Popup)

This section appears to be missing from the final document.

14 (Popup - Appendix B - Not available)

Appendix B of the Technical Support Document is not available electronically.

DOCKET NO: A-93-02
V-B-6

**TECHNICAL SUPPORT DOCUMENT FOR
SECTION 194.23: MODELS AND COMPUTER CODES**

Volume 3 of 3

**U. S. ENVIRONMENTAL PROTECTION AGENCY
Office of Radiation and Indoor Air
Center for the Waste Isolation Pilot Plant
401 M. Street, S. W.
Washington, DC 20460**

MAY 1998

DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)

CATEGORY II-A: EPA REPORTS/STUDIES AND OTHER MISCELLANEOUS
REPORTS

NO.	Date Sent to Docket	COMMENTS/ADDRESSEE Title and/or Subject	Date of Document
II-A-01	4-21-95	Ltr from L. Coe to J. Benetti Transmitting the "Audit Report for the Lawrence Berkeley Lab Quality Assurance Audit, Audit No. EPA-94-02	9/29/94
II-A-02	8-9-95	Sandia National Laboratory WIPP Quality Assurance Audit EA-95-01 of Pacific Northwest Laboratories Testing Activities Performed Under SNL AF-3339	4/12/95
II-A-3	8-9-95	Carlsbad Area Office (CAO) Audit A-95-01: A Quality Assurance Audit of the Westinghouse Waste Isolation Division (WID)	4/12/95
II-A-4	8-9-95	Florida State University Waste Isolation Pilot Plant Audit	7-11-95
II-A-5	8-9-95	Report of Audit of Florida State University for Waste Assignment (2-39)	5/16/94
II-A-6	8-9-95	Observation Report of Sandia National Laboratory Independent Review Team Activities: Intermediate Scale Borehole Test (Room C): In Situ Data Report January 1989-June 1993)	7/14/95
II-A-7	8-9-95	Observation Report of Sandia National Laboratory Independent Review Team Activities: Mechanical Compaction of Waste Isolation Pilot Plant Simulated Waste	7/24/95
II-A-8	8-9-95	Observation Report of Sandia National Laboratory Independent Review Team Activities: Application of Hydraulic Fracturing to Determine Virgin In Situ Stress State Around Waste Isolation Pilot Plant - In Situ Measurements	7/14/95
II-A-9	8-9-95	Observation Report of Sandia National Laboratory Independent Review Team Activities: Heated Axisymmetric Pillar Test (Room H): In Situ Data Report (February 1985-April 1987)	7/17/95
II-A-10	8-9-95	Observation Report of Sandia National Laboratory Independent Review Team Activities: Evaluation of Group 2 Boreholes	7/24/95
II-A-11	11/2/95	EPA Contractor Report/re: Review of WIPP Transuranic Waste Baseline Inventory Report (BIR)	9/13/95

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-A: EPA REPORTS/STUDIES AND OTHER MISCELLANEOUS
REPORTS**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-A-25	7/31/96	Transuranic Waste Baseline Inventory Report Rev 3 (DOE/CAO-95-1121)	6/96
II-A-26	10/15/96	EPA Report/EPA-402-R-96-010, Implementation of the Waste Isolation Pilot Plant Land Withdrawal Act, FY 1995 Report to Congress	8/96
II-A-27	11/7/96	DOE Peer Review Plans and Procedures	6/25/96
II-A-28	11/19/96	Report - "WIPP With Magnesium Oxide Back-Fill" Prepared For the NMAG under contract with the Hydrodynamics Group, Version 1.2	10/96
II-A-29	12/31/96	Michael Wallace/SNL Report, Records Package for Screening Effort NS11 Subsidence Associated With Mining Inside or Outside the Controlled Area WPO #40816	11/21/96
II-A-30	12/31/96	R.D. Wilmot/SNL Contractor Report - Galson Sciences, LTD Relationship of Side Effects to the Compliance Certification Application	11/1996
II-A-31	12/31/96	T.W. Hicks, Galson Sciences Hd., Subsidence Associated With Mining Screening Efforts S-15(b)	12/2/96
II-A-32	12/31/96	SNL Report, Phase II FEPs - Records Package, the Efforts of Salt Water Flooding on WIPP, WPO #40837	12/10/96
II-A-33	1/15/97	SNL Contractor Report - Galson Sciences Ltd. - Screening of FEPS Summary Tables, 9507a-9, Version 1	12/96
II-A-34	3/18/97	DOE/CAO Contractor Report, Performance Demonstration Program for Nondestructive Assay for the TRU Waste Characterization Program - Scoring Report - April 1996 Distribution- Prepared by Lockheed Idaho Technologies Co.	7/96
II-A-35	3/18/97	DOE/CAO Contractor Report, Performance Demonstration Program for Nondestructive Assay for the TRU Waste Characterization Program - Scoring Report - November 1996 Distribution- Prepared by Lockheed Idaho Technologies Co.	1/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-A: EPA REPORTS/STUDIES AND OTHER MISCELLANEOUS
REPORTS**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-A-46	10/14/97	Audit of the Department of Energy, Carlsbad Area Office- Peer Review Process.	
II-A-47	10/14/97	Audit of the Department of Energy, Carlsbad Area Office - Expert Judgement Elicitation.	
II-A-48	10/14/97	Audit of the Parameter Traceability and Qualification of Existing Data.	
II-A-49	10/14/97	Audit of the Sandia National Laboratories, Albuquerque, New Mexico. - T=0 Process.	
II-A -50	10/14/97	Inspection of CAO Audit of Idaho National Engineering and Environmental Laboratory.	
II-A-51	10/14/97	Inspection of CAO Audit of Los Alamos National Laboratory.	

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY II-B: EPA FACTUAL MEMORANDA

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-B-1	1/10/94	Ltr/J. Lytle, Comments on the 12/92 preliminary PA vol. 1-3	1/7/94
II-B-2	10/11/94	Trip Report: Workman/Offutt, No Migration Variance Petition Mtg. Held August 24-25 in Carlsbad, NM	undated
II-B-3	10/11/94	Trip Report: L. Wilson, Sandia National Lab WIPP Audit held July 26-27 (#A94-07)	8/4/94
II-B-4	4/20/95	Memo/J. Benetti/ Observation of DOE Data Quality Assessment Activities	undated
II-B-5	4/20/95	Trip to Idaho National Engineering Lab and Argonne National Lab	8/17/93
II-B-6	4/20/95	Memo/J. Benetti/Observation of Sandia Protocol for Qualification of Existing Data, August 25-26, 1994	undated
II-B-7	4/20/95	Trip Report for Jul 26-27 Trip to SNL WIPP Audit (#A94-07) (Same as Item II-B-3 above)	8/14/94
II-B-8	4/28/95	Trip Report/J. Benetti/Oak Ridge National Laboratory and Scientific Ecology	10/25/93
II-B-9	4/27/95	Trip Report/J. Benetti/Savannah River Site	11/30/93
II-B-10	4/27/95	Trip Report/J. Benetti/DOE Rocky Flats Plant, September 13-14, 1993	10/25/93
II-B-11	4/27/95	Trip Report/J. Benetti/Los Alamos National Laboratory, September 23-24, 1993	10/25/93
II-B-12	4/27/95	Trip Report/J. Benetti/Hanford Reservation and US Ecology LLW Site, 10/26-29/93	12/1/93
II-B-13	4/27/95	Trip Report/Sandia National Lab (SNL), Albuquerque, NM BRAGFLO Computer Code Training, 1/9-13/95	1/9/95
II-B-14	4/27/95	Trip Report/T. Peake/SNL, week of November 14, 1995	undated
II-B-15	10/12/95	Compliance Application Guidance Document for 40 CFR Part 194 Federal Register Draft	9/95

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY II-B: EPA FACTUAL MEMORANDA

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-B-29	7/3/96	EPA 402-B-95-014 Compliance Application Guidance for the Waste Isolation Pilot Plant: A Companion Guide to 40 CFR Part 194 (Also refer to: II-C-26)	3/96
II-B-30	7/11/96	Trip Rpt/K. Rogers/Carlsbad, NM: Waste Characterization Status Session/May 2-3, 1996	6/6/96
II-B-31	7/11/96	Trip Rpt/K. Rogers/Tour of Idaho National Engineering Laboratory and Argon National Laboratory-West/May 8-9, 1996	6/11/96
II-B-32	7/15/96	Trip Summary/T. Peake/Carlsbad, NM: Observation of DOE/State of NM Meeting, May 21-22, 1996, re: Culebra Retardation	6/12/96
II-B-33	7/15/96	Trip Summary/A. Wolbarst/Albuquerque, NM: Modeling Parameters Meeting, June 25, 1996	7/1/96
II-B-34	7/15/96	Trip Summary/S. Monroe/Albuquerque, NM: Closeout of Peer Review for PICs, July 8, 1996	7/10/96
II-B-35	7/15/96	Trip Summary/T. Peake/Conceptual Model Peer Review Panel Closeout Meeting, July 1-2, 1996	7/15/96
II-B-36	7/31/96	Trip Summary/K. Rogers/Los Alamos, NM: LANL STTP Audit April 29-May 1, 1996	6/6/96
II-B-37	8/15/96	Trip Summary/J. Oliver/DOE/EPA Technical Exchange on Engineered Barrier and Passive Institutional Controls, Albuquerque, NM, July 30-31, 1996	8/6/96
II-B-38	8/21/96	Trip Report/S.J. Chern/Albuquerque, NM August 9, 1996 Observation of DOE's Waste Characterization Peer Review Closeout	8/12/96
II-B-39	10/17/96	Trip Report/T. Peake/Report with Materials from GRASP-INV and SECO Computer Code Presentations	9/22/96
II-B-40	11/7/96	Trip Summary/K. Rogers/Hands on fracture-Matrix Transport (FMT) Code Training	11/7/96
II-B-41	5/14/97	QA Trip Reports/M. Eagle	5/8/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-C: CORRESPONDENCE SENT TO PERSONS OUTSIDE THE
AGENCY**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-C-15	4/10/95	Ltr. to Mark Frei, DOE, from Bill Gunter, Change from Waste Character Program Document (from WIPP to TRU)	2/17/93
II-C-16	4/10/95	Ltr. to G. Dials, from B. Gunter, "long-term repository seals"	11/7/94
II-C-17	4/10/95	Ltr. to S.P. Schneider, DOE from Larry Weinstock, Comments on Draft versions of Remote Handled Transuranic Waste Study Plan	11/8/93
II-C-18	4/10/95	Ltr. to G. Dials from Bill Gunter: "Specific Comments on WIPP Regulatory Compliance Strategy & Management Plan"	2/28/94
II-C-19	4/10/95	Ltr. to Jim Mewhinney, DOE, "Scenario Draft Position Paper"	10/21/94

ITEMS IIC-20 THRU IIC-23 PREVIOUSLY FILED IN ERROR (CATEGORY IV-C-1 THRU C-4)

II-C-20	4/5/95	Transmittal Memo Draft Compl. Appl. Guidance Document (Previous No: IV-C-1)	3/21/95
II-C-21	4/11/95	Ltr from L. Weinstock to G. Dials about technical exchange presentations by DOE and contractors on the subject of engineered barriers and quality assurance (Previous No: IV-C-2)	3/16/95
II-C-22	4/11/95	Ltr from A. Colli to J. Mewhinney on understanding computer codes and exploring ways to run them on EPA's computers (Previous No: IV-C-3)	1/24/95
II-C-23	4/11/95	Thank you ltr from L. Weinstock to G. Dials for presentations (Previous No: IV-C-4)	2/7/95
II-C-24	11/2/95	Ltr., to G. Dials from L. Weinstock/Comments on DOE's WIPP Draft Compliance Certification Application (DCCA)	10/31/95
II-C-25	1/30/96	Ltr to G. Dials, DOE from L. Weinstock transmitting staff Review of the DOE's Draft Title 40 CFR Part 191 compliance Certification Application (DCCA)	1/30/96
II-C-26	4/3/96	Ltr to G. Dials/DOE, transmitting EPA's Compliance Application Guidance (CAG)	3/28/96

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-C: CORRESPONDENCE SENT TO PERSONS OUTSIDE THE
AGENCY**

NO.	Date Sent to Docket	COMMENTS/ADDRESSEE Title and/or Subject	Date of Document
II-C-39	02/04/97	Ltr/EPA/F. Marcinowski to SRIC/D. Hancock, follow-up to EPA/WIPP Stakeholder Meetings in New Mexico held January 21-23, 1997 w/ enclosures	01/29/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY II-D: CORRESPONDENCE FROM PERSONS OUTSIDE THE AGENCY

NO.	Date Sent to Docket	COMMENTS/ADDRESSEE Title and/or Subject	Date of Document
II-D-1	1/10/94	Ltr to C. Petti from S. Schneider, DOE re: provide additional info. as a result of EPA/DOE meeting on WIPP QA	10/12/93
II-D-2	4/16/94	Ltr. from DOE to M. Oge and M. Shapiro re: Transmitting the Experimental Program Plan (EPP) for comments	1/14/94
II-D-3	7/21/94	Report from DOE "Independent Technical Review of the Bin and Alcove Test programs at the WIPP"	12/93
II-D-4	7/21/94	Ltr from W. Weart, SNL/WIPP transmitting test plans requested by EPA	6/10/94
II-D-5	7/21/94	Rpt. from DOE "WIPP Transuranic Waste Baseline Inventory Rpt." Book 1 of 2	6/94
II-D-6	7/21/94	Rpt. from DOE "WIPP Transuranic Waste Baseline Inventory Rpt." Book 2 of 2	6/94
II-D-7	7/21/94	Rpt. from DOE "TRU Waste Characterization QA Program Plan - Revision B "DRAFT"	7/8/94
II-D-8	8/31/94	Ltr. from G. Dials to M. Oge; re: Systems Prioritization Method Process	6/6/94
II-D-9	8/31/94	Rpt from Oak Ridge Nat'l Lab re: Integrated Data Base for 1993: U.S. Spent Fuel and Radioactive Waste Inventories, Projections	3/19/94
II-D-10	8/31/94	WIPP Tour and Overview to M. Nichols, AA for OAR/EPA	8/11/94
II-D-11	10/11/94	Ltr. to L. Weinstock, transmitting draft working maps of WIPP (see map tube with this number)	8/24/94
II-D-12	10/11/94	Draft Position Paper - Scenario Development for Postclosure PA of the WIPP. Input in Systems Prioritization & Project Technical Baseline	9/9/94
II-D-13		Ltr /L. Lovejoy to R. Bills, re: WIPP Stakeholder Mtg	1/09/95
II-D-14	10/11/94	Summary of INTRAVAL and Geostatistics Expert Group	1992
II-D-15	11/25/94	Performance based waste acceptance criteria preliminary baseline assumptions	10/24/94

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY II-D: CORRESPONDENCE FROM PERSONS OUTSIDE THE AGENCY

NO.	Date Sent to Docket	COMMENTS/ADDRESSEE Title and/or Subject	Date of Document
II-D-32	4/5/95	Ltr. from G. Dials to B. Gunter, Position Paper on PA Methodology	08/17/94
II-D-33	4/12/95	Memo/NMED to Interested Parties re Revised WIPP Permit Application	10/26/94
II-D-34	6/23/94	Ltr/M. Bennington to C. Byrum (Reg 6) re: Radiological Environmental Surveillance Air Sampling-WIPP Site	06/07/94
II-D-35	8/17/94	Ltr/G. Dials to L. Weinstock, transmitting copy of System Prioritization Method Implementation Plan Method (SPM)	08/17/94

**THE FOLLOWING ITEMS (II-D-36 to II-D-49) WERE PREVIOUSLY MISFILED IN CATEGORY IV-D
AS IV-D-1 THRU IV-D-16.**

II-D-36	4/5/95	Ltr From M. McFadden to L. Lovejoy on Disposal Room and Cutting Position Paper (Previous No: IV-D-1)	2/23/95
II-D-37	4/5/95	Ltr. from G. Dials to R. Neill on the Carlsbad position, documented in the minutes of the "Panel 1 Utilization Plan" meeting (Previous No: IV-D-2)	1/12/95
II-D-38	4/7/95	Ltr from G. Dials dated 3/3/95 to L. Weinstock on issues on recent EPA Tech Forum held in D.C. (Previous No: IV-D-3)	3/3/95
II-D-39	4/7/95	DRAFT 40 CFR 191 Compliance Certification Application for WIPP. Ltr to L. Weinstock from G. Dials dated 3/31/95. (Previous No: IV-D-4)	3/31/95
II-D-40	4/7/95	Ltr. addressed to Robert Bills- DOE, Carlsbad, NM in reference to comments on 12/15/94-Draft/Paper Non-Salado Flow & Transport. (Previous No: IV-D-5)	1/20/95
II-D-41	4/7/95	Ltr/Matthews to Weinstock, Comments on Draft TRU Waste Characterization Quality Assurance Program Plan (QAPP) (Previous No: IV-D-6)	3/13/95
II-D-42	4/10/95	Ltr. to Lovejoy from Michael H. McFadden, DOE, Enclosing three reports from Tech Supp Group: "Findings for Perform Assessment Parameter List", "Findings on Large Scale Seals Test Program", and "Findings on Culebra Tracer Testing " (Previous No: IV-D-7)	2/9/95

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY II-D: CORRESPONDENCE FROM PERSONS OUTSIDE THE AGENCY

NO.	Date Sent to Docket	COMMENTS/ADDRESSEE Title and/or Subject	Date of Document
II-D-56	10/30/95	Pre-Release Comments, (EEG) re: Draft CAG for WIPP	5/25/95
II-D-57	10/30/95	Pre-Release Comments, SRIC, re: Draft CAG for WIPP	5/25/95
II-D-58	10/30/95	Pre-Release Comments, NM/AG, re: Draft CAG for WIPP	5/26/95
II-D-59	10/30/95	Pre-Release Comments, NM/ED, re: Draft CAG for WIPP	5/26/95
II-D-60	10/30/95	Pre-Release Comments, CCNS, re: Draft CAG for WIPP	5/26/95
II-D-61	10/30/95	R. H. Neill, EEG, ltr to G. Dials, DOE, re: Abandonment Of Northern Experimental Area of the WIPP Underground	9/26/95
II-D-62	11/2/95	D. Hancock (SRIC), Public Comments on DOE's WIPP Draft Compliance Certification Application	10/16/95
II-D-63	11/2/95	Atty. Gen., of New Mexico , Public Comments on DOE's WIPP Draft Compliance Certification Application	10/13/95
II-D-64	11/6/95	Ltr. to EEG R. H. Neill from G. Dials (DOE) Responding EEG Concerns Regarding Deactivation of WIPP Experimental Area	10/23/95
II-D-65	11/6/95	Ltr from G. Dials/DOE, to R. Trovato/EPA, Second Major Revision of The WIPP Disposal Decision Plan	10/12/95
II-D-66	11/6/95	Ltr, EEG/R.H. Neill, Comments on DOE's Draft Compliance Certification Application w/attached DOE letter dated 6/16/92, and EEG comments dated 12/27/91 and 8/10/90	10/23/95
II-D-67	11/6/95	Ltr/G. Dials/DOE transmitting the "Remote Handled Transuranic Waste Study" (DOE/CAO 95-1095)	10/11/95
II-D-68	11/6/95	Ltr/G. Dials/DOE Transmitting DOE Report Entitled "Sealing System Design Report (DOE/WIPP 95-3117)"	10/23/95
II-D-69	11/13/95	Ltr from L. A. Lovejoy, AG NM, to L. Weinstock expressing concerns about the format of 11/7-9/95 Technical Exchange between DOE and EPA	11/2/95
II-D-70	1/22/96	Ltr from L.A. Lovejoy NM Assistant Attorney General to Re: December 1995 Technical Exchange Meeting with DOE on Geohydrology	11/30/95

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY II-D: CORRESPONDENCE FROM PERSONS OUTSIDE THE AGENCY

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-D-85	6/26/96	Transmittal of Chapter 3, "Facility Description," and Supporting documents of the Compliance Certification Application: a. Transmittal ltr/G.Dials/DOE to L.Weinstock/EPA (6/24/96) b. Chapter 3 (Facility Description) of the CCA (6/21/96) c. Appendix RE3, Reference Expansion (6/21/96) d. Appendix PCS, Panel Closure System (DOE/WIPP 96-2150, 01/11/96) e. Appendix SEAL, Shaft Seals Design (DOE/WIPP 95-3117, Oct., 1995)	6/24/96
II-D-86	6/26/96	Transmittal of Appendices in support of Chapter 4 (previously submitted at II-D-83) of the Compliance Certification Application: a. Transmittal letter/G.Dials/DOE to L.Weinstock/EPA (6/24/06) b. Appendix WAC, Waste Isolation Criteria (Rev. 5, April 1996) c. Appendix WAP, Waste Analysis Plan (Chapter C, DOE/WIPP 91-005)	6/24/96
II-D-87	6/26/96	Transmittal of Appendix QAPD (Quality Assurance Program Plan) in Support of Chapter 5 (previously submitted at II-D-84) of the Compliance Certification Application: a. Transmittal ltr/G.Dials/DOE to L. Weinstock/EPA (6/24/96) b. DOE Carlsbad Area Office QAPD (CAO-94-1012, April 1996) c. Sandia National Laboratories QAPD (Rev. R, 7/31/95) d. Westinghouse Waste Isolation Division QAPD (WP 13-1, 5/3/96)	6/24/96
II-D-88	7/2/96	Transmittal of Appendices in support of Chapter 2 (previously submitted) of the Compliance Certification Application: a. Transmittal letter from G. Dials/DOE to L. Weinstock/EPA (6/24/96) b. Appendix CLI, Long-Term Climate Variability at the WIPP (SAND 91-7055, Nov. 1992) c. Appendix DEL, Drilling Requirements and Practices in the Delaware Basin (draft, Mar. 1996) d. Appendix USDW, Underground Sources of Drinking Water at and Near the WIPP Site (prepared by John Hart and Associates Not dated)	6/24/96

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY II-D: CORRESPONDENCE FROM PERSONS OUTSIDE THE AGENCY

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-D-96	8/14/96	DOE transmittal of Appendix WCA to the Compliance Certification Application For the WIPP	8/12/96
II-D-97	8/20/96	DOE transmittal of MASS Attachment 4-1 to the Compliance Certification Application for the WIPP	Not dated
II-D-98	8/20/96	DOE Transmittal of WCA Attachment WCA.8.1 to the Compliance Certification Application for the WIPP	Not dated
II-D-99	8/21/96	Ltr/J. Maes/DOE to F.Marcinowski/EPA, transmitting DOE Report WIPP/CAO-96-3168 dated June 4, 1996 to be included as Appendix EPIC in DOE's Compliance Certification Application	8/20/96
II-D-100	11/8/96	Ltr./Secretary of Energy/H.R. O'Leary/transmitting DOE's Compliance Certification Application (CCA). (The CCA is docketed at II-G-1.)	10/29/96
II-D-101	2/6/97	Ltr/CARD/D. Mitchell and G. Harris to EPA/F. Marcinowski, regarding EPA/NM Stakeholder meetings	1/25/97
II-D-102	4/10/97	Ltr/EEG/R.H. Neill to EPA/F. Marcinowski, transmitting unpublished brief dated August 3, 1990, entitled <u>The "KARST" Issue and Its Relevance to WIPP</u>	3/20/97
II-D-103	4/17/97	Ltr/EEG/R.H. Neill to Dr. Wilson, Chairman WIPP Conceptual Models Peer Review Panel regarding EEG Report (EEG-55)	4/9/97
II-D-104	4/23/97	Jay Shelton/Santa Fe Prep School Abstract entitled "Where is the WIPP Catastrophe that Justifies WIPP Phobia?"	No Date
II-D-105	4/23/97	Ltr/Janet Greenwald, CARD/ Lee Lysne, CCNS/Don Hancock, SRIC/Dan Kerlinsky, NMPSR to EPA/M. Nichols regarding DOE's CCA and the Public Comment Period	3/28/97
II-D-106	5/1/97	Ltr/Sisters of Loretto/Penelope McMullen, SL to EPA/C. Browner regarding WIPP Public Hearings in New Mexico	2/22/97
II-D-107	5/1/97	Ltr/Sisters of Loretto/P. McMullen to EPA/F. Marcinowski responding to EPA letter of 4/10/97 (filed II-C-41)	No Date

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY II-D: CORRESPONDENCE FROM PERSONS OUTSIDE THE AGENCY

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-D-116	9/4/97	Ltr./NM-AAG/L. Lovejoy to EPA/L. Weinstock transmitting two reports: (a) Rebuttal: Technical Review of the HARTMAN Scenario: Implications for WIPP dated July 28, 1997 (b) The HARTMAN Scenario Revisited: Implications for WIPP	8/25/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY II-E: EPA MEMORANDA OF MEETINGS WITH OUTSIDE PERSONS

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-E-1	1/13/94	Minutes of EPA/DOE Working Session Mtg. on WIPP Disposal Room Model	10/7/93
II-E-2	1/13/94	Minutes of EPA/DOE Technical Exchange Mtg. re: Uncertainty and Sensitivity Analysis	10/26/93
II-E-3	1/13/94	Minutes of EPA/DOE Mtg. to discuss revised approach to achieving regulatory compliance for WIPP	12/16/93
II-E-4	3/9/94	NAS Meeting on WIPP (includes agenda, attendees, copies of presentations, etc.) held 12/14-15/93	2/16/94
II-E-5	4/16/94	Minutes of EPA/DOE Technical Exchange Mtg. to review EPA comments on 1992 WIPP PA and discuss DOE strategy toward WIPP disposal decision	3/16/94
II-E-6	4/16/94	Minutes of EPA/DOE Technical Exchange Mtg. to review technical issues related to 1992 WIPP PA	4/8/94
II-E-7	6/24/94	Minutes of EPA/DOE Technical Exchange Mtg. on Access to PA Computer Codes	5/11/94
II-E-8	6/27/94	Minutes of meeting w/ Region 6 and Contractor re: Biennial Environmental Compliance Report (BECR)	11/5/93
II-E-9	6/27/94	Results of Environmental Fact Finding Trip to WIPP	3/23/94
II-E-10	6/27/94	Results of Meeting w/ New Mexico Environmental Department to discuss BECR.	6/3/94
II-E-11	6/27/94	DOE/EPA Technical Exchange Mtg. on WIPP Hydrology, held in Carlsbad, NM	5/3-5/94
II-E-12	7/21/94	Minutes of EPA/DOE Technical Exchange on Geology, Hydrology, and GW flow and transport at the WIPP site	6/28/94
II-E-13	8/31/94	Summary report of meeting w/ SNL on PA computer codes	7/22/94
II-E-14	8/31/94	Memo to A. Ortiz from T. Margulies with a copy of his presentation at SNL on Human Intrusion and Analysis of PA results	undated

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY II-E: EPA MEMORANDA OF MEETINGS WITH OUTSIDE PERSONS

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-E-29	10/2/96	Minutes of the December 1995 EPA/DOE Technical Exchange On Culebra Hydrology Issues	7/3/96
II-E-30	10/23/96	Meeting Notes: DOE NDA/NDE/IWG Meeting, 8/2/96	8/2/96
II-E-31	11/7/96	Minutes of DOE/EPA Technical Exchange WIPP Actinide Source- Term Program	8/22/96
II-E-32	11/7/96	Minutes of EPA/DOE Technical Exchange on Engineered Alternatives and Passive Institutional Controls	8/12/96
II-E-33	12/31/96	Minutes of DOE/EPA Technical Exchange, Waste Isolation Pilot Plant Waste Characterization	12/11/96
II-E-34	02/04/97	Summary of EPA/WIPP Stakeholder Meetings in New Mexico with EEG, CARD, NMAG, CCNS and SRIC (including handouts) held January 21-23, 1997	1/21- 23/97
II-E-35	02/06/97	Minutes of the DOE/EPA Technical Exchange: Castile Brine Reservoir and Water Injection Issues	12/19/96
II-E-36	03/07/97	Summary of EPA/EEG Meeting on 2/24/97 re: EEG's Comments on DOE's WIPP Compliance Certification Application	2/24/97
II-E-37	7/8/97	Memo/M. Sheppard to Docket: Summary of EPA/EEG meeting held on June 17, 1997, regarding Performance Assessment Input Parameters with: Atch. A - EPA - Update of Agency Review - Briefing - May 15, 1997	7/1/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY II-F INTERAGENCY REVIEW MATERIALS (Includes drafts sent to other Government agencies for comment, a copy of each document accompanying such drafts, all comments by such agencies, and any written responses of EPA to these comments.)

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-F-1	08/01/95	DOE's Draft Title 40 CFR 191, Compliance Certification (DCCA) for the Waste Isolation Pilot Plant/WIPP, Transmittal letter dated 7/28/95	July 1995 Update
II-F-2	10/30/95	Pre-Release Comments for the draft Compliance Application Guidance (CAG) document from DOE	5/24/95

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-G: DEPARTMENT OF ENERGY'S COMPLIANCE CERTIFICATION
APPLICATION FOR THE WASTE ISOLATION PILOT PLANT**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
Vol. V		Appendix BIR (cont.) Report	Transuranic Waste Baseline Inventory
		Appendix BRAGFLO	WIPP Performance Assessment User's Manual For BRAGFLO
		Appendix CCDFGF	Design Document For CCDFGF and GRIDFLO
		Appendix CLI	Long-Term Climate Variability At the Waste Isolation Pilot Plant
		Appendix CODELINK	The WIPP 1996 Performance Assessment Codes and Their Linkages
		Appendix CUTTINGS	WIPP Performance Assessment User's Manual for CUTTINGS_S
		Appendix D&D	Conceptual Decontamination and Decommissioning Plan For the Waste Isolation Pilot Plant
		Appendix DEF	Deformation
		Appendix DEL	Delaware Basin Study
		Appendix DMP	Delaware Basin Drilling Monitoring Plan
Vol. VI		Appendix DVR	Design Validation Report
Vol. VII		Appendix DVR (cont.) Appendix EBS	Design Validation Report Engineered Alternatives Cost/Benefit Study
Vol. VIII		Appendix EBS (cont.) Appendix EMP	Engineered Alternatives Cost/Benefit Study Waste Isolation Pilot Plant Environmental Monitoring Plan
		Appendix EPIC	Effectiveness of Passive Institutional Controls In Reducing Inadvertent Human Intrusion Into the Waste Isolation Pilot Plant For Use In Performance Assessments
		Appendix FAC	Facies Variability and Post-Depositional Alterations Within the Rustler Formation In the Vicinity of the Waste Isolation Pilot Plant
Vol. IX		Appendix GCR	Geological Characterization Report

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-G: DEPARTMENT OF ENERGY'S COMPLIANCE CERTIFICATION
APPLICATION FOR THE WASTE ISOLATION PILOT PLANT**

NO.	Date Sent to Docket	COMMENTS/ADDRESSEE Title and/or Subject	Date of Document
		Appendix SECOTP2D	WIPP Performance Assessment User's Manual For SECOTP2I
		Appendix SER	WIPP Site Environmental Report
		Appendix SMP	Subsidence Monitoring Plan
		Appendix SOTERM	Source Term
	Vol. XVIII	Appendix SUM	Summary of Site-Characterization Studies Conducted From 1983 Through 1987
		Appendix T-LD	Generation of an Ensemble of Culebra Transmissivity Fields Conducted to Steady-State and Transient Pressure Data Using GRASP-INV
		Appendix USDW	Underground Sources of Drinking Water
		Appendix VCMF	Volatile Organic Compound Monitoring Plan
	Vol. XIX	Appendix WAP	Waste Analysis Plan
		Appendix WCA	Waste Characterization Analysis
		Appendix WCL	Waste Component Limits
		Appendix WRAC	Waste Removal After Closure
	Vols. XX- XXI	Appendix XRE	Reference Expansion

Ref. #	AUTHOR(s)	REFERENCE
1.	Adams, J.E. 1944.	Upper Permian Ochoa Series of the Delaware Basin, West Texas and Southeastern New Mexico. American Association of Petroleum Geologists Bulletin, Vol. 28, No. 11, November, 1944, pp. 1596-1625.
2.	Aldrich Catalog/Handbook of Fine Chemicals. 1994.	Aldrich Chemical Company, Inc., Milwaukee, WI.
3.	Alexander, A.E., and P. Johnson. 1949.	Colloid Science. New York, NY: Oxford University Press, Vol. 1.
4.	Alexander, M. 1994.	Biodegradation and Bioremediation. Academic Press, N.Y.
5.	Al-Hussaini, M. 1981.	Tensile Properties of Compacted Soils, Laboratory Shear Strength of Soil, ASTM STP 740, R. N. Yong and F.C. Townsend, Eds., American Society for Testing Materials, pp. 207-225.
6.	Algermissen, S.T., and Perkins, D.M. 1976.	A Probabilistic Estimate of Maximum Ground Acceleration in the Contiguous United States. Open-file Report 76-416, pp. 1-45. U.S. Geological Survey. Superseded by USGSOFR 82-1033
7.	Allard, B., H. Kipatsi, and J.O. Liljenzin. 1980.	Expected Species of Uranium, Neptunium, and Plutonium in Neutral Aqueous Solutions, Journal of Inorganic Nuclear Chemistry, Vol. 42, 1015-1027.
8.	Amyx, J.W., Bass, D.M., Jr., and Whiting, R.L. 1960.	Petroleum Reservoir Engineering, Physical Properties. ISBN 07-001600-3, McGraw-Hill Book Company, New York, NY. (derived from equation 2-33) pp. 78.
9.	ASME (American Society of Mechanical Engineers), 1989.	Quality Assurance Program Requirements for Nuclear Facilities, NQA-1, American Society of Mechanical Engineers, New York, New York.
10.	ASME (American Society of Mechanical Engineers), 1990.	ASME NQA-2a-1990, Part 2.7, May 31, 1990 Quality Assurance Requirements for Nuclear Facility Applications.
11.	ASME (American Society of Mechanical Engineers), 1990.	Quality Assurance Program Requirements for the Collection of Scientific and Technical Information for Site Characterization of High-Level Nuclear Waste Repositories, ASME NQA-3-1989, March 23, 1990.
12.	Anderson, R.Y., 1978	Report to Sandia Laboratories on Deep Dissolution of Salt, Northern Delaware Basin, New Mexico.
13.	Anderson, R.Y., and Kirkland, D.W. 1980.	Dissolution of Salt Deposits by Brine Density Flow. Geology, Vol. 8, no. 2, pp. 66-69.
14.	Anderson, R.Y., Dean, W.E., Kirkland, Jr., D.W., and Snider, H. I. 1972.	Permian Castile Varved Evaporite Sequence, West Texas and New Mexico. Geological Society of America Bulletin, Vol. 83, pp. 59-86.
15.	Anderson, R., P.L. Vaughn, Stoelzel, and O'Brien. 1996.	Memorandum to Margaret Chu, Subject: Justification of Brine Pocket Volume Uncertainty, July 22, 1996.
16.	Andersson, J. E., Ed. 1989.	The Joint SKI/SKB Scenario Development Project. SKB Technical Report 89-35, Stockholm, Sweden.
17.	Argüello, J.G., and T.M. Torres. 1988.	Thermal Effects of RH-TRU Waste Emplacement on WIPP Storage Room Thermal/Structural Response. SAND88-2217. Sandia National Laboratories, Albuquerque, NM.

Ref. #	AUTHOR(s)	REFERENCE
31.	Barnhart, B.J., Campbell, E.W., Martinez, E., Caldwell, D.E., and Hallett, R. 1980.	Potential Microbial Impact on Transuranic Wastes Under Conditions Expected in the Waste Isolation Pilot Plant (WIPP), Annual Report, October 1, 1978- Sept 30, 1979, LA-8297-PR, Los Alamos National Laboratory, Los Alamos NM.
32.	Barr, G.E., W.B. Miller, and D.D. Gonzalez, 1983.	Interim Report on the Modeling of the Regional Hydraulics of the Rustler Formation, SAND83-0391, Albuquerque, NM: Sandia National Laboratories.
33.	Barrows, L.J., S-E. Shaffer, W.B. Miller, and J.D. Fett, 1983.	Waste Isolation Pilot Plant (WIPP) Site Gravity Survey and Interpretation, SAND82-2922, Albuquerque, NM, Sandia National Laboratories.
34.	Baskaran, M., P.H. Santschi, G. Benoit, and B.D. Honeyman. 1992.	Scavenging of Thorium Isotopes by Colloids in Seawater of the Gulf of Mexico, <i>Geochemica et Cosmochemica Acta</i> . Vol. 56, 3375-3388.
35.	Batchelor, G.K. 1973.	An Introduction to Fluid Dynamics. First paperback edition. Cambridge University Press, London, UK.
36.	Bates, J.K., J.P. Bradley, A. Teetsov, C.R. Bradley, and M. Buchholtz. 1992.	Colloid Formation During Waste Form Reaction: Implications for Nuclear Waste Disposal, <i>Science</i> , Vol. 256, 649-561.
37.	Bates, R.L., and J.A. Jackson, eds. 1980.	Glossary of Geology, American Geological Institute, Falls Church, VA. Second edition, ISBN: 0-913312-15-0. THIS DOCUMENT IS READILY AVAILABLE IN MOST LIBRARIES!
38.	Bear, J. 1988.	Dynamics of Fluids in Porous Media. Dover Publications
39.	Bear, J., and Verruijt, A. 1987.	Modeling Groundwater Flow and Pollution. D. Reidel Publishing Company, Boston, MA.
40.	Beauheim, R.L., 1986.	Hydraulic-Test Interpretations for Well DOE-2 at the Waste Isolation Pilot Plant (WIPP) Site. SAND86-1364, Albuquerque, NM, Sandia National Laboratories.
41.	Beauheim, R.L. 1987.	Analysis of Pumping Tests of the Culebra Dolomite Conducted at the H-3 Hydropad at the [WIPP] Site. SAND86-2311. Sandia National Laboratories, Albuquerque, NM.
42.	Beauheim, R.L., 1987.	Interpretation of the WIPP-13 Multipad Pumping Test of the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site. SAND87-2456.
43.	Beauheim, R.L., 1987.	Interpretations of Single-Well Hydraulic Tests Conducted At and Near the Waste Isolation Pilot Plant (WIPP) Site, 1983-1987, SAND87-0039, Albuquerque, NM, Sandia National Laboratories.
44.	Beauheim, R.L. 1989.	Interpretation of H-11b4 Hydraulic Tests and the H-11 Multipad Pumping Test of the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site, SAND89-0536.
45.	Beauheim, R.L. 1996.	Culebra H-19 Hydraulic Test Analyses, Albuquerque, NM: Sandia National Laboratories. (Copy on file in the Sandia WIPP Cental Files, Sandia National Laboratories, Albuquerque, NM as WPO38401.)
46.	Beauheim, R.L. 1996.	Personal Communication Richard L. Beauheim, Sandia National Laboratories, Albuquerque, New Mexico, and Barbara J. Graves, John Hart and Associates, P.A., July 17, 1996.
47.	Beauheim, R.L., B. W. Hassinger, and J.A. Klaiber, 1983.	Basic Data Report for Borehole Cabin Baby-1 Deepening and Hydrologic Testing, WTSD-TME-020, Albuquerque, NM, U.S. DOE.
48.	Beauheim, R.L., Dale, T.F., and Pickens, J.F. 1991.	Interpretations of Single-Well Hydraulic Tests of the Rustler Formation Conducted in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, 1988-1989. SAND89-0869. Sandia National Laboratories, Albuquerque, NM.

Ref. #	AUTHOR(s)	REFERENCE
67.	Bertram-Howery, S.G., and P.N. Swift, 1990.	Status Report: Potential for Long-Term Isolation by the Waste Isolation Pilot Plant Disposal System. SAND90-0616.
68.	Bertram-Howery, S.G., M.G. Marietta, R.P. Rechard, P.N. Swift, D.R. Anderson, B.L. Baker, J.E. Bean, Jr., W. Beyeler, K.F. Brinster, R.V. Guzowski, J.C. Helton, R.D. McCurley, D.K. Rudeen, J.D. Schreiber, and P. Vaughn, 1990.	Preliminary Comparison with 40 CFR Part 191, Subpart B for the Waste Isolation Pilot Plant, December 1990, SAND90-2347, Albuquerque, NM, Sandia National Laboratories.
69.	Bethke, C.M., 1994.	The Geochemist's Workbench - version 2.0 - A Users Guide to Rxn, Act2, Tact, React, Gtplot. Unpublished code, Hydrogeology Program, University of Illinois at Champaign-Urbana, Illinois.
70.	Birkeland, Peter W. 1984.	Soils and Geomorphology, Oxford University Press, ISBN 0-19-503435-X
71.	BLM (U.S. Bureau of Land Management) and John Hart and Associates, P.A. (JHA), 1995.	Personal communication, R. Hansen, JHA and J. Amos, R. Manus, S. Shaw, T. O'Brian, and C. Cranston, BLM.
72.	BLM (U.S. Bureau of Land Management) and John Hart and Associates, P.A. (JHA), 1996.	Personal communication, R. Hansen, JHA and J. Amos, BLM.
73.	BLM (U.S. Bureau of Land Management) and the Westinghouse Electric Corporation, 1996.	Personal communication, J. Johns, Westinghouse and S. Shaw, BLM.
74.	Blom, G. 1989.	Probability and Statistics: Theory and Applications. Springer-Verlag, New York, NY. p. 216. NWM Library, QA 273. B56 1989.
75.	Borns, D.J., 1985.	Marker Bed 139: A Study of Drillcore from a Systematic array, SAND85-0023, Albuquerque, NM, Sandia National Laboratories.
76.	Borns, D.J. 1987.	The Geologic Structures Observed in Drillhole DOE-2 and Their Possible Origins: Waste Isolation Pilot Plant. SAND86-1495. Albuquerque, NM: Sandia National Laboratories.
77.	Borns, D.J. 1987.	Rates of Evaporite Deformation: The Role of Pressure Solution. SAND85-1599. Albuquerque, NM: Sandia National Laboratories.
78.	Borns, D.J., and Shaffer, S-E. 1985.	Regional Well-Log Correlation in the New Mexico Portion of the Delaware Basin. SAND83-1798. Sandia National Laboratories, Albuquerque, NM.
79.	Borns, D.J., L.J. Barrows, D.W. Powers, and R.P. Snyder, 1983.	Deformation of Evaporites Near the Waste Isolation Pilot Plant (WIPP) Site, SAND82-1069, Albuquerque, NM, Sandia National Laboratories.
80.	Brausch, L.M., A.K. Kuhn, and J.K. Register, 1982.	Natural Resources Study, Waste Isolation Pilot Plant (WIPP) Project, Southeastern, New Mexico, WTSD-TME-3156, Albuquerque, NM, D'Appolonia Consulting Engineers.
81.	Bredenhoft, J.D., Riley, F.S., and Roeloffs, E.A. 1987	Earthquakes and groundwater. Earthquakes and Volcanos, Vol 19, no. 4, pp. 138-146.
82.	Brodsky, N.S. 1990.	Crack Closure and Healing Studies in WIPP Salt Using Compressional Wave Velocity and Attenuation

Ref. #	AUTHOR(s)	REFERENCE
99.	Buddemeier, R.W., and J. R. Hunt. 1988.	Transport of Colloidal Contaminants in Groundwater: Radionuclide Migration at the Nevada Test Site. <i>Applied Geochemistry</i> 3, 535-548.
100.	Budescu and Wallsten, 1987.	in <i>Judgmental Forecasting</i> , ed. G. Wright and P. Aytar. John Wiley & Sons, Chichester, England.
101.	Butcher, B.M. 1994.	Memorandum to Distribution, January 6, 1994. Subject: A Model for Cuttings Release Waste Properties. Sandia National Laboratories, Albuquerque, NM.
102.	Butcher, B.M. 1996.	Memo to M.S. Tierney, RE: QAP9-1 Documentation of the Initial Waste Water Content for the CCA, January 29, 1996. WPO 30925.
103.	Butcher, B.M. 1996.	"QAP9-2 Documentation of the Initial Waste Water Content for the CCA," Memo, June 29, 1996. (Copy on file in Sandia WIPP Central File.)
104.	Butcher, B.M., and F.T. Mendenhall, 1993.	Summary of the Models Used for the Mechanical Response of Disposal Rooms in the Waste Isolation Pilot Plant with Regard to Compliance with 40 CFR 191, Subpart B, SAND92-0427, Albuquerque, NM, Sandia National Laboratories.
105.	Butcher, B.M., T.W. Thompson, R.G. VanBuskirk, and N.C. Patti. 1991b.	Mechanical Compaction of Waste Isolation Pilot Plant Simulated Waste. SAND90-1206. Albuquerque, NM: Sandia National Laboratories.
106.	Bynum, R.V. 1996.	Memo to M.S. Tierney and C. Stockman. "Update of Uncertainty Range and Distribution for Actinide Solubilities to be Used in CCA NUTS Calculation." WPO 38535.
107.	Callahan, G.D. 1993.	"Appendix A: Further Discussion of the TRU Waste Models," A Summary of the Models Used for the Mechanical Response of Disposal Rooms in the Waste Isolation Pilot Plant with Regard to Compliance to 40 CFR 191, Subpart B. B.M. Butcher and F.T. Mendenhall. SAND92-0427. Sandia National Laboratories, Albuquerque, NM. This is a subdocument of Ref # 104.
108.	Callahan, G.D. 1994.	SPECTROM-32: A Finite Element Thermomechanical Stress Analysis Program Version 4.06, RSI-0531, RE/SPEC Inc., Rapid City, SD. WPO 36814.
109.	Canon, Wayne. 1996.	Personal Communication between W. Canon, Supervisor, State Engineer, Albuquerque District, and Barbara J. Graves, John Hart and Associates, P. A., May 30, 1996.
110.	Capilla, J.E., J.J. Gómez-Hernández, and A. Sahuquillo. 1992.	"Conditioning of Transmissivity Fields to Piezometric Data." Presentation at INTRAVAL Meeting, San Antonio, TX, November, 1992. (Copy on file in the Sandia WIPP Central Files, Albuquerque, NM.)
111.	Carrera, J., and S.P. Neuman. 1986.	Estimation of Aquifer Parameters Under Transient and Steady State Conditions, 2, Uniqueness, stability, and solution algorithms, <i>Water Resour. Res.</i> , 22(2), 211-227, 1986.
112.	Cartwright, Jr., L.D. 1930.	Transverse section of Permian Basin, west Texas and southeastern New Mexico. <i>American Association of Petroleum Geologists Bulletin</i> , Vol. 14, pp. 969-981.
113.	Casas, E., and Lowenstein, T.K. 1989.	Diagenesis of saline pan halite: comparison of petrographic features of Modern, Quaternary and Permian halites. <i>Journal of Sedimentary Petrology</i> , Vol. 59, pp. 724-739.
114.	Case, John B., 1995.	Conceptual Design for Operational Phase Panel Closure Systems, DOE-WIPP-95-2057. U.S. Department of Energy, Carlsbad Area Office, Carlsbad, NM.
115.	Cauffman, T.L., A.M. LaVenue, and J. P. McCord, 1990.	Ground-Water Flow Modeling of the Culebra Dolomite. Volume II: Data Base, SAND89-7068/2, Albuquerque, NM, Sandia National Laboratories.

Ref. #	AUTHOR(s)	REFERENCE
134.	Clark, D.L. and Tait, C.D. 1996.	Monthly Reports Under SNL Contract AP2274, Sandia WIPP Central File A:WBS 1.1.10.1.1. These data are qualified under LANL QAPJP CST-OSD-QAP1-001/0.
135.	Clark, D.L., D.E. Hobart, and M.P. Neu. 1995.	Actinide Carbonate Complexes and Their Importance in Actinide Environmental Chemistry, Chem Revs. Vol. 95, 25-48.
136.	Cleveland, J.M. 1979.	Critical review of plutonium equilibria of environmental concern. In Chemical Modeling in Aqueous Systems: Speciation, Solubility and Kinetics, 176th Meeting of the American Chemical Society, Miami Beach, FL, September 11-13, 1978; E.A. Jenne, Ed.; American Chemical Society Symposium Series: 321-338.
137.	Cleveland, J.M. 1979.	The Chemistry of Plutonium, La Grange Park, IL: American Nuclear Society.
138.	Collins, R.E. 1961.	Flow of Fluids Through Porous Materials. Reinhold, New York, NY.
139.	Comans, R.N.J., and J.J. Middleburg. 1987.	Sorption of Trace Metals on Calcite: Applicability of the Surface Precipitation Model, Geochemica et Cosmochemica Acta., Vol. 51, no. 9, 2587-2591.
140.	Cook, C.W. 1982.	Underground Scanning With an Impulse Radar, Sandia National Laboratories, SAND82-0470, 1982.
141.	Cooper, J.B. 1962.	Ground-Water Investigations of the Project Gnome Area, Eddy and Lea Counties, New Mexico, U.S. Geological Survey TEI-802, Open-File Report, 67 p. 17 Figures.
142.	Cooper, J.B., and Glanzman, V.M. 1971.	Geohydrology of Project Gnome Site, Eddy County, New Mexico USGS Professional Paper 712-A
143.	Corapcioglu, M.Y., and Jiang, S. 1993.	"Colloid-Facilitated Groundwater Contaminant Transport," Water Resources Research. Vol. 29, no. 7, 2216-2226.
144.	Corbet, T. 1995.	"NS-9: Justification of SECO2D Approximation for PA Transport Calculations." Summary Memo of Record to D.R. Anderson, September 21, 1995. SWCF-A:1.1.6.3. Sandia National Laboratories, Albuquerque, NM. Contained in WPO 30802.
145.	Corbet, T. 1995.	Two-Dimensional Assumption for Culebra Calculations. Summary Memo of Record for NS-9. Memo of 21 September. SWCF-A 1.1.6.3:PA:QA: MGT:FSD. Sandia National Laboratories, Albuquerque, NM.
146.	Corbet, T.F. 1994.	"Evolution of Patterns of Regional Groundwater Flow in Southeastern New Mexico: Response to Post-Pleistocene Changes in Climate," Abstracts with Programs, 1994 Annual Meeting, The Geological Society of America, October 24-27, 1994. SAND94-1856A, Seattle, WA. Vol. 26, no. 7, 414. WPO 23733.
147.	Corbet, T.F. and Knupp, P.M. 1996	The Role of Regional groundwater Flow in the Hydrogeology of the Culebra Member of the Rustler Formation at the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico., SAND96-2133, Sandia National Laboratories, Albuquerque, NM.
148.	Corbet, T., and Swift, P. 1996.	Memo to M. Teirney. Re: Distribution for Non-Salado Parameter for SECOFL2D: Climate Index, April 12, 1996. WPO 37465.
149.	Corey, A.T. 1954.	"The Interrelation Between Gas and Oil Relative Permeabilities," Producer's Monthly. Vol. XIX, no. 1, 38-41.
150.	Cotton, F.A., and G. Wilkinson. 1988.	Advanced Inorganic Chemistry, 5th ed. New York, NY: John Wiley & Sons.
151.	Cranwell, R.M., R.V. Guzowski, J.E. Campbell, and N.E. Ortiz. 1990.	Risk Methodology for Geologic Disposal of Radioactive Waste: Scenario Selection Procedure, NUREG/CR-1667 SAND80-1428 Albuquerque, NM Sandia National Laboratories

Ref. #	AUTHOR (s)	REFERENCE
167.	Deal, D.E., and R.J. Abitz, D.S.Belski, J.B.Case, M.E. Crawley, R.M. Deshler, P.E. Drez, C.A. Givens, R.B. King, B.A. Lauctes, J. Myers, S. Niou, J.M. Peitz, W.M. Roggenthen, J.R. Tyburski, and M.G. Wallace, 1989.	Brine Sampling and Evaluation Program, 1988 Report, DOE/WIPP 89-015, Section 4.1, 1989.
168.	Deal, D.E., and Roggenthen, W.M. 1989.	"The Brine Sampling and Evaluation Program (BSEP) at WIPP: Results of Four Years of Brine Seepage Data," Waste Management '89, Waste Processing, Transportation, Storage and Disposal, Technical Programs and Public Education, Tucson, AZ, February 26-March 2, 1989. Ed. R.G. Post. University of Arizona, Tucson, AZ. Vol. 1, 405-406.
169.	Deal, D.E., J.B. Case, R.M. Deshler, P.E. Drez, J. Nyers, and J.A. Tyburski. 1989a.	Brine Sampling and Evaluation Program Phase II Report. DOE-WIPP-87-010. Carlsbad, NM: U.S. Department of Energy Waste Isolation Pilot Plant.
170.	Deal, D.E., R.J. Abitz, D.S. Belski, J.B. Clark, M.E. Crawley and M.L. Martin. 1991a.	Brine Sampling and Evaluation Program 1989 Report. DOE_WIPP_91-009. Carlsbad, NM: U.S. Department of Energy Waste Isolation Pilot Plant.
171.	Deal, D.E., R.J. Abitz, J. Myers, J.B. Case, D.S. Belski, M.L. Martin and W.M. Roggenthen. 1991b.	Brine Sampling and Evaluation Program 1990 Report. DOE-WIPP 91-036. Carlsbad, NM: U.S. Department of Energy Waste Isolation Pilot Plant.
172.	Deal, D.E., R.J. Abitz, J. Myers, M.L. Martin, D.J. Milligan, R.W. Sobocinski, P.P.J. Lipponer, and D.S. Belski, 1993.	Brine Sampling and Evaluation Program, 1991 Report, DOE/WIPP93-026, Carlsbad, NM, Westinghouse Electric Corporation.
173.	Delacroix, D. Jr. 1977.	Historical Information on WIPP. Letter to David Veith, April 21, 1977. Sandia National Laboratories, Albuquerque, NM. (Copy on file in Sandia WIPP Central Files.)
174.	Dence, M.R., Grieve, R.A.F., and Robertson, P.B., 1977.	Terrestrial Impact Structures: Principle Characteristics and Energy Considerations. In Impact and Explosion Cratering, D.J. Roddy, R.O. Pepin, and R.B. Merrill, eds., pp. 247-275. Pergamon Press, New York, NY.
175.	Deutsch, C.V., and Journel, A.G. 1992.	GSLIB, Geostatistical Software Library and User's Guide, Oxford University Press, New York.
176.	Dietz, R.S., August 1961.	Astroblemes, Scientific American, Vol. 205, #2, p 50-58.
177.	DOE (U.S. Department of Energy), 1979.	Draft Environmental Impact Statement. DOE/EIS-0026-D. Office of Assistant Secretary for Defense Programs, Washington, D.C. Superseded by Ref # 178.
178.	DOE (U.S. Department of Energy), 1980.	Final Environmental Impact Statement, Waste Isolation Pilot Plant. DOE/EIS-0026, Volumes 1-2, Office of Environmental Restoration and Waste Management, Washington, D.C.
179.	DOE (U.S. Department of Energy), 1980.	Waste Isolation Pilot Plant Safety Analysis Report, Washington, D.C., U.S. Department of Energy, Vols. 1-5. Superseded by Ref # 202.
180.	DOE (U.S. Department of Energy), 1983,	Results of Site validation Experiments, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico, TME 3177, U.S. Department of Energy, Albuquerque Operations, Albuquerque, New Mexico. (LTM- Vol II)

Ref. #	AUTHOR(s)	REFERENCE
200.	DOE (U.S. Department of Energy), 1995	Remote-Handled Transuranic Waste Study, DOE/CAO 95-1095, October, 1995.
201.	DOE (U.S. Department of Energy), 1995	Transuranic Waste Characterization Quality Assurance Program Plan. DOE/CAO-94-1010, Revision 0, April 30, 1995. Carlsbad, NM.
202.	DOE (U.S. Department of Energy), 1995	Waste Isolation Pilot Plant Safety Analysis Report. DOE/WIPP-95-2065, Revision 0, November 1995. Carlsbad, NM.
203.	DOE (U.S. Department of Energy), 1995	Waste Isolation Pilot Plant Seal System Design Report, DOE/WIPP-95-3117. Washington, D.C.
204.	DOE (U.S. Department of Energy), 1995	Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1995, DOE/WIPP 95-2094, U.S. Department of Energy (DOE), Carlsbad, New Mexico.
205.	DOE (U.S. Department of Energy), 1995	WWIS Software Quality Assurance Plan. DOE/CAO-95-1108. Version 0, May 1995, Carlsbad, NM.
206.	DOE (U.S. Department of Energy). 1996.	CAO Management Plan. CAO-96-1187, Carlsbad Area Office, Carlsbad, NM.
207.	DOE (U.S. Department of Energy). 1996.	CAO Team Procedure (TP) 10.5 Rev. 0, Carlsbad Area Office, Carlsbad, NM.
208.	DOE (U.S. Department of Energy). 1996.	Waste Acceptance Criteria for the Waste Isolation Pilot Plant, DOE/WIPP-96-069, Revision 5, April 1996. Carlsbad, NM.
209.	DOE (U.S. Department of Energy). 1996.	Waste Isolation Pilot Plant Disposal Phase Supplemental Environmental Impact Statement Implementation Plan. DOE/EIX-0026-S-2-IP, REV. 0, Carlsbad Area Office, Carlsbad, NM.
210.	DOE (U.S. Department of Energy). 1996.	WIPP Waste Characterization Sampling and Analysis Methods Manual, DOE/WIPP 91-043, 1991. Rev. 1. Sections 630 & 650 attached.
211.	DOE (U.S. Department of Energy). 1996.	WIPP Waste Information System Software Design Description, DOE/CAO-96-1111, Revision 0, April 1996, Carlsbad, NM (September 1996 revision 0)
212.	DOE (U.S. Department of Energy). and State of New Mexico. 1981.	Consultation and Cooperation Agreement. Appendix A to the Stipulated Agreement Resolving Civil Action, 81-0363JB, State of New Mexico vs. United States Department of Energy, United States District Court, Albuquerque, NM.
213.	DOI (U.S. Department of the Interior), Bureau of Mines. 1975.	Mineral Facts and Problems, Bulletin 667, Washington, D.C.
214.	DOI (U.S. Department of the Interior). 1981	A preliminary Analysis of Gravity and Aeromagnetic Surveys of the Timber Mountain Area, Southern Nevada, Geological Survey Open File Report, 1981.
215.	DOI (U.S. Department of the Interior). 1991	Ultra Low Frequency Electromagnetic Fire Alarm System for Underground Mines, Bureau of Mines, Report of Investigations RI 9377, 1991.
216.	DOI (U.S. Department of the Interior). 1995.	43 CFR Part 3160, Onshore Oil and Gas Operations, Federal and Indian Oil and Gas Leases Drilling Operations. Subpart 3162, Requirements for Operating Rights, Owners and Operators. Subpart 3162.3-4, Well abandonment. 43 CFR Chapter 2. October 9, 1995. 53 Federal Register 22847, June 17, 1988. Bureau of Land Management, Washington, D.C.
217.	DOI (U.S. Department of the Interior). 1995.	43 CFR Part 3593, Boreholes and Samples. Subpart 3593.1, Core and Testhole Cores, Samples, Cuttings. 43 CFR Chapter 2, October 9, 1995. 53 Federal Register 22847, June 17, 1988. Bureau of

Ref. #	AUTHOR(s)	REFERENCE
234.	EPA (U.S. Environmental Protection Agency). 1986.	Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd ed., Office of Solid Waste and Emergency Response, Washington, D.C. This document is readily available and is not included.
235.	EPA (U.S. Environmental Protection Agency), 1988.	Compendium Method TO-14, The Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using SUMMA [®] Passivated Canister Sampling and Gas Chromatographic Analysis, May 1988.
236.	EPA (U.S. Environmental Protection Agency). 1994.	Requirements fo Quality Assurance Project Plans for Environmental Data Operations. EPA QA/R-5. Quality Assurance Management Staff. U.S. Environmental Protection Agency (Draft Interim Final). Washington, D.C. This document is readily available and is not included.
237.	EPA (U.S. Environmental Protection Agency) 1995.	Compliance Application Guidance for 40 CFR Part 194, EPA 402-R-95-014, Office of Radiation and Indoor Air, Washington, D.C. March 29, 1996. This document is readily available and is not included.
238.	EPA (U.S. Environmental Protection Agency), 1996.	Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations. Response to Comments Document for 40 CFR Part 194. EPA 402-R-96-001. Washington, D.C.: U.S. Environmental Protection Agency. This document is readily available and is not included.
239.	EPA (U.S. Environmental Protection Agency), 1996.	Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations Background Information Document. EPA 402-R-96-002. Washington, D.C.: U.S. Environmental Protection Agency. This document is readily available and is not included.
240.	Ephraim, J.H., C. Peterson, M. Norden, and B. Allard. 1995.	Potentiometric titrations of humic substances: Do ionic strength effects depend on the molecular weight?, Environmental Science and Technology, Vol. 29, 622-628.
241.	Eugster, H.P., C.E. Harvie, and J.H. Weare. 1980.	Mineral Equilibria in the Six-Component Seawater System Na-K-Mg-Ca-SO ₄ -Cl-H ₂ O, at 25°C, Geochimica et Cosmochimica Acta, Vol. 44, No. 9, 1335-1347.
242.	Faith, S., P. Spiegler, and K.R. Rehfeldt. 1983.	The Geochemistry of Two Pressurized Brines from the Castile Formation in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site. April 1983. EEG-21.
243.	Fanghänel, Th., V. Neck, and J.I. Kim. 1995.	Thermodynamics of Neptunium(V) in Concentrated Salt Solutions: II. Ion Interaction (Pitzer) Parameters for Np(V) Hydrolysis Species and Carbonate Complexes. Radiochimica Acta, Vol. 69, 169-173.
244.	Felmy, A.R., and D. Rai. 1992.	An Aqueous Thermodynamic Model for a High Valence 4:2 Electrolyte H ⁺ -SO ₄ ²⁻ in the System Na-K ⁺ -Li ⁺ -NH ₄ ⁺ -SO ₄ ²⁻ -HSO ₄ ⁻ -H ₂ O to High Concentration, Journal of Solution Chemistry. Vol. 21, no. 5, 407-423.
245.	Felmy, A.R., and J.H. Weare. 1986.	The Prediction of Borate Mineral Equilibria in Natural Waters: Application to Searles Lake, California, Geochimica et Cosmochimica Acta. Vol. 50, no. 12, 2771-2783.
246.	Felmy, A.R., D. Rai, and M.J. Mason. 1991.	The Solubility of Hydrated Thorium(IV) Oxide in Chloride Media: Development of an Aqueous Ion-Interaction Model, Radiochimica Acta. Vol. 55, no. 4, 177-185.
247.	Felmy, A.R., D. Rai, and R.W. Fulton. 1990.	The Solubility of AmOHCO ₃ (c) and the Aqueous Thermodynamics of the System Na ⁺ -Am ³⁺ -HCO ₃ ⁻ -OH ⁻ -H ₂ O, Radiochimica Acta. Vol. 50, no. 4, 193-240.
248.	Felmy, A.R., D. Rai, J.A. Schramke, and J.L. Ryan. 1989.	The Solubility of Plutonium Hydroxide in Dilute Solution and in High-Ionic-Strength Chloride Brines, Radiochimica Acta. Vol. 48, no 1/2, 29-35.

Ref. #	AUTHOR(s)	REFERENCE
267.	Gomez-Hernandez, J.J. and X-H Wen. 1993.	Gaussian Optimization, Presentation at INTRAVAL Meeting, Berkeley, CA, March 15-16, 1993. (Copy on file in the Sandia WIPP Central Files, Sandia National Laboratories, Albuquerque, NM).
268.	Gonzalez, D.D. 1983.	Groundwater Flow in the Rustler Formation Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico: Interim Report. SAND82-1012. Albuquerque, NM, Sandia National Laboratories.
269.	Goodwin, B.W., Stephens, M.E., Davison, C.C., Johnson, L.H., and Zach, R. 1991.	Scenario Analysis for the Postclosure Assessment of the Canadian Concept for Nuclear Fuel Waste Disposal. AECL-10969, Whiteshell Laboratories, Pinawa, Manitoba, Canada.
270.	Graf, D.L., A.J. Eardley, and A.F. Shimp. 1961.	A Preliminary Report on Magnesium Carbonate Formation in Glacial Lake Bonneville, J. Geol. Vol. 69, 219-223.
271.	Grenthe, I. and H. Wanner. 1992.	Guidelines for the Extrapolation to Zero Ionic Strength. NEA-TBD-2, Revision 2, Guf-sur-Yvette, France: OECD Nuclear Energy Agency.
272.	Grieve, R.A.F. 1987.	Terrestrial Impact Structures. Annual Review of Earth and Planetary Sciences, Vol. 15, pp. 245-270. Ann. Rev. Earth Planet Sci., © Annual Reviews, Inc. 0084-6597/87/0515-0245\$02.00
273.	Grindrod, P. 1993.	"The Impact of Colloids on the Migration and Dispersal of Radionuclides Within Fractured Rock," Journal of Containment Hydrology. Vol. 13, no. 1-4, 167-181.
274.	Grindrod, P., and Worth, D.J. 1990.	Radionuclide and Colloid Migration in Fractured Rock: Model Calculations. SKI Technical Report 91:11, Swedish Nuclear Power Inspectorate, Stockholm, Sweden.
275.	Griswold, G.B., 1977.	Sites Selection and Evaluation Studies of the Waste Isolation Pilot Plant (WIPP), Los Medaños, Eddy County, NM, SAND77-0946, Albuquerque, New Mexico, Sandia National Laboratories.
276.	Guzowski, R.V. 1990.	Preliminary Identification of Scenarios for the Waste Isolation Pilot Plant, Southeastern New Mexico. SAND90-7090, Sandia National Laboratories, Albuquerque, NM. WPO 25771.
277.	Hale, W.E., Hughes, L.S., and Cox, E.R. 1954.	Possible Improvement of Quality of Water of the Pecos River by Diversion of Brine at Malaga Bend, Eddy County, NM. Pecos River Commission New Mexico and Texas, in cooperation with United States Department of the Interior, Geological Survey, Water Resources Division, Carlsbad, NM.
278.	Halliday, I. 1964.	The Variation in the Frequency of Meteorite Impact with Geographic Latitude. Meteoritics, Vol. 2, No. 3, pp. 271-278.
279.	Hansen, F.D. 1996.	Review Plan: Shaft Seal System Design for the Waste Isolation Pilot Plant (WIPP). Sandia National Laboratories, Albuquerque, NM.
280.	Hansen, F.D. and E.H. Ahrens, 1996.	"Large-Scale Dynamic Compaction of Natural Salt," 4th International Conference on the Mechanical Behavior of Salt, Montreal, Quebec, Canada, June 17-18, 1996. SAND96-0792C. Sandia National Laboratories, Albuquerque, NM WPO 39544.
281.	Hansen, F.D., E.H. Ahrens, V.C. Tidwell, J.R. Tillerson, and N.S. Brodsky. 1995.	Dynamic Compaction of Salt: Initial Demonstration and Performance Testing, Rock Mechanics Proceedings of the 35th U.S. Symposium, University of Nevada, Reno, NV, June 5-7, 1995. Eds. J.J.K. Daemen and R.A. Schultz. SAND94-2313C. Brookfield, VT: A.A. Balkema. 755-760.
282.	Harmand, B., and Sardin, M. 1994.	"Modeling the Coupled Transport of Colloids and Radionuclides in a Fractured Natural Medium," Chemistry and Migration Behavior of Actinides and Fission Products in the Geosphere, Proceedings of the Fourth International Conference, Charleston, SC, December 12-17, 1993. R. Oldenbourg Verlag, Munich. Vol. 66/67, 691-699.

Ref. #	AUTHOR(s)	REFERENCE
301.	Hobart, D.E. 1990.	Actinides in the Environment, Proceedings of the Robert A. Welch Foundation Conference on Chemical research, No. XXXIV: 50 years With Transuranium Elements. October 22-23, 1990.
302.	Hobart, D.E., and R. Moore. 1996.	Analysis of Uranium (VI) Solubility Data for WIPP Performance Assessment: Implementation of Analysis Plan AP-028, Copy on file in Sandia WIPP Central File.
303.	Hobart, D.E., and Moore, R. 1996.	Draft Analysis of Uranium (VI) Solubility Data for WIPP Performance Assessment, Sandia National Laboratories, March 28, 1996. WPO 33703.
304.	Hobart, D.E., C.J. Bruton, F.J. Millero, I-Ming Chou, K.M. Trauth, D.R. Anderson. 1996.	Estimates of the Solubilities of Waste Element Radionuclides in WIPP Brines, SAND96-0098. Sandia National Laboratories, Albuquerque, NM.
305.	Hobart, D.E., Samhoun, K., and Peterson, J.R. 1982.	Spectroelectrochemical Studies of the Actinides: Stabilization of Americium (IV) in Aqueous Carbonate Solution, Radiochimica Acta v. 31, pp. 139-145.
306.	Hodgkinson, D.P. and Sumerling, T.J., 1989.	"A Review of Approaches to Scenario Analysis for Repository Safety Assessment." In Proceedings of the IAEA/CEC/NEA (OECD) Symposium on Safety Assessment of Radioactive Waste Repositories (Paris, 1989). OECD/NEA, Paris, France.
307.	Holcomb, D.J., and M. Shields. 1987.	Hydrostatic Creep Consolidation of Crushed Salt With Added Water. SAND87-1990. Albuquerque, NM: Sandia National Laboratories
308.	Holt, R.M., and Powers, D.W. 1984.	Geotechnical Activities in the Waste Handling Shaft Waste Isolation Pilot Plant (WIPP) Project Southeastern New Mexico. WTSD-TME-038. U.S. Department of Energy, Carlsbad, NM.
309.	Holt, R.M., and Powers, D.W. 1986.	Geotechnical Activities in the Exhaust Shaft. DOE-WIPP-86-008. U.S. Department of Energy, Carlsbad, NM.
310.	Holt, R.M., and D.W. Powers. 1987.	Rustler Formation in the Waste-Handling and Exhaust Shafts, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico, pp. 26-35 in the Rustler Formation at the WIPP Site. Report EEG-34. State of New Mexico Environmental Evaluation Group, Santa Fe, NM. SEE:Chaturvedi, L., ed. 1987. This is a subdocument of Ref # 121.
311.	Holt, R.M., and D. W. Powers, 1990.	Geologic Mapping of the Air Intake Shaft at the Waste Isolation Pilot Plant, DOE-WIPP 90-051, Carlsbad, NM, Westinghouse Electric Corporation.
312.	Hopmans, J.W., and Overmars, B. 1986.	"Presentation and Application of an Analytical Model to describe Soil Hydraulic Properties," Journal of Hydrology. Vol. 87, no. 1-2, 135-143.
313.	Hora, S.C., D. von Winterfeldt, and K.M. Trauth, 1991.	Expert Judgement on Inadvertent Human Intrusion into the Waste Isolation Pilot Plant, SAND90-3063, Albuquerque, New Mexico, Sandia National Laboratories.
314.	Horita, J., T.J. Friedman, B. Lazar, and H.D. Holland. 1991.	The Composition of Permian Seawater. Geochimica et Cosmochimica Acta., Vol. 55, 417-432.
315.	Howard, B.A. 1996.	Memo from B.A. Howard to Mel Marietta, April 3, 1996, RE: Future Mining Events in Performance Assessment. Attachment: Extent of Mining Position Paper, Revision 1. WPO 38571.
316.	Howard, C.L., Jensen, A.L., Jones, R.L., and Peterson, T.P. 1993.	Room Q data report: Test borehole data from April 1989 through November 1991, SAND92-1172

Ref. #	AUTHOR(s)	REFERENCE
334.	Jaeger, J.C. and N.G.W. Cook, 1979.	Fundamentals of Rock Mechanics, 3rd Edition, Chapman and Hall, London.
335.	Jarolimek, L., M.J. Timmer, and R.F. McKinney, 1983.	Geotechnical Activities in the Exploratory Shaft - Selection of the Facility Interval Waste Isolation Pilot Plant (WIPP) Project Southeastern New Mexico, TME 3178, Albuquerque, NM, U.S. DOE.
336.	Jensen, M. 1993.	Conservation and Retrieval of Information—Elements of a Strategy to Inform Future Societies about Nuclear Waste Repositories. Final Report of the Nordic Nuclear Safety Research Project KAN - 1.3., August 1993.
337.	Johnson, G.L., and L.M. Toth. 1978.	Plutonium(IV) and Thorium(IV) Hydrous Polymer Chemistry, ORNL/TM-6365, Oak Ridge, TN: Oak Ridge National Laboratory, Chemistry Division.
338.	Johnson, K.S. 1987.	Development of the Wink Sink in West Texas due to Salt Dissolution and Collapse. In Karst hydrology. Proc. 2nd Conference, Orlando, 1987. B.F. Beck, W.L. Wilson, eds. Oklahoma Geological Survey, Norman, USA. Balkema. pp. 127-136.
339.	Jones, C.L., 1978.	Test Drilling for Potash Resources: Waste Isolation Pilot Plant Site, Eddy County, New Mexico, U.S. Geological Survey Open-File Report 78-592, Denver, CO, U.S. Geological Survey. Vols 1 and 2
340.	Jones, C.L. 1981.	Geologic Data for Borehole ERDA-6, Eddy County, New Mexico. Open-File Report 81-468. U.S. Geological Survey, Denver, CO.
341.	Jones, C.L., Bowles, C.G., and Bell, K.G. 1960.	Experimental Drillhole Logging in Potash Deposits of the Carlsbad District, New Mexico. Open-File Report 60-84, pp. 25. U.S. Geological Survey.
342.	Jones, C.L., M.E.Cooley, and G.O., Bachman, 1973.	Salt Deposits of the Los Medaños Area, Eddy and Lea Counties, New Mexico, USGS-4339-7, Denver, CO, U.S. Geological Survey. This document has been superseded by USGSOFR 73-135.
343.	Jones, T.L., Kelly, V.A., Pickens, J.F., Upton, D.T., Beauheim, R.L., and Davies, P.B. 1992.	Integration of Interpretation Results of Tracer Tests Performed in the Culebra Dolomite at the Waste Isolation Pilot Plant Site. SAND92-1579. Sandia National Laboratories, Albuquerque, NM.
344.	Journel, A.J., and Ch. J. Huijbregts. 1978.	Mining Geostatistics, New York, NY: Academic Press, 1978.
345.	Kaplan, M.F. 1982.	Archaeological Data as a Basis for Repository Marker Design. ONWI-354 UC-70, October 1982.
346.	Kaplan, S., and B.J. Garrick, 1981.	On the Quantitative Definition of Risk, Risk Analysis, Vol. 1, No. 1, pp.11-27. 0272-4332/81/0300-0011\$03.00/1 © Society for Risk Analysis
347.	Kärnbränslesakerhet. 1978.	Handling of Spent Nuclear Fuel and Final Storage of Vitriified High Level Reprocessing Waste. Kärnbränslesakerhet (now SKB), Stockholm, Sweden. 1 cy INIS MF 4390, 1 cy INIS MF 4391, 1 cy INIS MF 4461
348.	Kato, C. Sato, T., Smorawinska, M., and Horikoshi, K. 1994.	"High Pressure Conditions Simulate Expression of Chloramphenicol acetyltransferase Regulated by the Iac Promoter in Escherichia coli," FEMS Microbiology Letters. Vol. 122, nos. 1-2, 91-96.
349.	Katz, J.J., G.T. Seaborg, and L.R. Morss. 1986.	The Chemistry of Actinide Elements, 2 vols., New York, NY: Chapman and Hall.
350.	Kehrman, R.F. 1990.	Discontinuation of Environmental Dosimetry Program, letter to J.A. Mewhinney, July 24, 1990.

Ref. #	AUTHOR(s)	REFERENCE
370.	Korpusov, G.V., Patrusheva, E.N., and Dolidze, M.S. 1975.	"The Study of Extraction Systems and the Methods of Separation of Trivalent Transuranium Elements Cm, Bk, and Cf,"Sov. Radiochem. v. 17, pp. 230-236, cited in Katz, J.J., Seaborg, G.T., and Morss, L.R. 1986. The Chemistry of the Actinide Elements, Second Edition, Chapman and Hall, New York.
371.	Kraus, K.A. 1956.	Hydrolytic behavior of the heavy elements. In Proceedings of the First United Nations International Conference on the Peaceful Uses of Atomic Energy, Geneva. 245-257.
372.	Krefta, M. 1994.	Personal memorandum to T. Mallick titled Magnetic Field Calculations for WIPP Magnetic Markers.
373.	Labreche, D.A., Callahan, L., DeVries, and J.D. Osnes. 1993.	Comparison of Two Geomechanical analysis codes for WIPP Disposal Room Modeling: SANCHO and SPECTROM-32. Topical Report RSI-0461, RE/SPEC Inc., Albuquerque, NM.
374.	Lambert, S.J., 1978,	Geochemistry of Delaware Basin Ground Water, Circular 159, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico, pp. 33-38. This is a subdocument of Circular 159 Ref # 18.
375.	Lambert, S.J., 1983.	Dissolution of Evaporites in and Around the Delaware Basin, Southeastern, New Mexico and West Texas, SAND82-0461, Albuquerque, NM, Sandia National Laboratories.
376.	Lambert, S.J. 1983.	Evaporite dissolution relevant to the WIPP site, northern Delaware Basin, southeastern New Mexico, Materials Research Society Symposium Proceedings 15: Scientific Basis for Nuclear Waste management VI. Ed. D.G. Brookins. New York, NY: Elsevier Science Publishing Company. 291-298. SAND82-1416C
377.	Lambert, S.J. 1987.	Feasibility Study: Applicability of Geochronologic Methods Involving Radiocarbon and other Nuclides to the Groundwater Hydrology of the Rustler Formation, Southeastern New Mexico. SAND86-1054. Sandia National Laboratories, Albuquerque, NM.
378.	Lambert, S.J. and D.M. Harvey, 1987.	Stable-Isotope Geochemistry of Groundwaters In the Delaware Basin of Southeastern New Mexico, SAND87-0138, Albuquerque, NM, Sandia National Laboratories.
379.	Lambert, S.J. and J.A. Carter, 1984.	Uranium-Isotope Disequilibrium in Brine Reservoirs of the castile formation, Northern Delaware Basin, Southeastern New Mexico. I:Principles and Methods, SAND83-0144, Albuquerque, NM, Sandia National Laboratories.
380.	Lambert, S.J. and J.A.Carter, 1987.	Uranium-Isotope Systematics in Groundwaters of the Rustler Formation, Northern Delaware Basin, Southeastern New Mexico. I:Principles and Preliminary Results, SAND87-0388, Albuquerque, NM, Sandia National Laboratories.
381.	Lang, W.B. 1939.	Salado formation of the Permian basin. American Association of Petroleum Geologists Bulletin, Vol. 23, pp. 1569-1572.
382.	Lang, W.B. 1942.	Basal beds of Salado formation in Fletcher potash core test near Carlsbad, New Mexico. American Association of Petroleum Geologists Bulletin, Vol. 26, pp. 63-79.
383.	Lappin, A.R. 1988.	Summary of Site-Characterization Studies Conducted from 1983 through 1987 of the Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico. SAND88-0157/VC-70. Sandia National Laboratories, Albuquerque, NM.

Ref. #	AUTHOR(s)	REFERENCE
398.	Lieser, K.H., B. Gleitsmann, and T. Steinkopff. 1986b.	Sorption of trace elements or radionuclides in natural systems containing groundwater and sediments. <i>Radiochimica Acta</i> . Vol. 40: 33-37.
399.	Lieser, K.H., B. Gleitsmann, S. Peschke, and T. Steinkopff. 1986a.	Colloid Formation and Sorption of Radionuclides in Natural Systems. <i>Radiochimica Acta</i> . Vol. 40: 39-47.
400.	Lieser, K.H., R. Hill, U. Mühlenweg, R.N. Singh, T. Shu-De, and Th. Steinkopff. 1991.	Actinides in the Environment, <i>Journal of Radioanalytical and Nuclear Chemistry, Articles</i> , Vol. 147, no. 1, 117-131.
401.	Liscum-Powell, J., J.S. Rath, L.C. Sanchez, and H.R. Trellue. 1996.	WIPP PA Analysis Report for EPAUNI: Estimating Probability Distribution of EPA Unit Loading in the WIPP Repository for Performance Assessment Calculations. Document Record Package for WBS 1.2.07.1.1 Sandia National Laboratories, Albuquerque, NM.
402.	Logan, S.E., and Berbano, M.C. 1978.	Development and Application of a Risk Assessment Method for Radioactive Waste Management. EPA 520/6-78-005. U.S. Environmental Protection Agency, Washington, D.C. Vols. 1-4.
403.	Loken, M.C. 1994.	SMC Thermal Calculations, RSI Calculation No. A141-GE-05, prepared for Parsons Brinckerhoff, San Francisco, CA. RE/SPEC, Inc., Rapid City, SD.
404.	Loken, M.C., and Chen, R. 1994.	Rock Mechanics of SMC, RSI Calculation NO A141-GE-07, prepared for Parsons Brinckerhoff, San Francisco, CA. RE/SPEC, Inc., Rapid City, SD.
405.	Long, G.J., and Associates, Inc. 1976.	Interpretation of Geophysical Data, Los Medanos and Vicinity, Lea and Eddy Counties, New Mexico. Report to Sandia National Laboratories.
406.	Long, G.J. and Associates, Inc., 1977,	Final Report, Waste Isolation Pilot Plant (WIPP), Los Medanos Area, Eddy and Lea Counties, New Mexico, report submitted to Sandia National Laboratories, Albuquerque, New Mexico.
407.	Lord, K.J., and Reynolds, W.E., eds. 1985.	Archaeological Investigations of Three Sites within the WIPP Core Area. Prepared for the U.S. Army Corps of Engineers (COE), Albuquerque District in NM. Eddy County, NM, Chambers Consultants and Planner, Albuquerque, NM.

Ref. #	AUTHOR(s)	REFERENCE
410.	Lowenstein, T.K. 1988.	Origin of depositional cycles in a Permian saline giant: the Salado (McNutt Zone) evaporites of New Mexico and Texas. Geological Society of America Bulletin, Vol. 100, #4, April 1988, pp. 592-608.
411.	Luker, R.S., T.W. Thompson, and B.M. Butcher. 1991.	Compaction and Permeability of Simulated Waste, Rock Mechanics as a Multidisciplinary Science: Proceedings of the 32nd U.S. Symposium, The University of Oklahoma, Norman, OK, July 10-12, 1991. Ed. J-C. Roegiers. SAND90-2368C. Brookfield, VT: A.A. Balkema. 693-702.
412.	Lyklema, J. 1978.	Surface chemistry of colloids in connection with stability. In The Scientific Basis of Flocculation; K.J. Ives, Ed.,; Sijthoff and Noordhoff: Dordrecht, The Netherlands: 3-36.
413.	Lynch, A.W., and R.G. Dosch. 1980.	Sorption Coefficients for Radionuclides on Samples from the Water-Bearing Magenta and Culebra Members of the Rustler Formation. SAND80-1064. Albuquerque, NM: Sandia National Laboratories.
414.	Lynch, A.W., Dosch, R.G., and Hills, C.R. 1981.	Migration of Cesium-137 Through a Solid Core of Magenta Dolomite Taken from the Rustler Formation in Southeastern New Mexico. SAND80-1259, Sandia National Laboratories, Albuquerque, NM. WPO 24234.
415.	Machette, Michael N. 1985.	Calcic Soils of the Southwestern United States, in Soils and Quaternary Geology of the Southwestern United States. Special Paper 203, Weide, D.L., ed., pp. 1-21. Geological Society of America.
416.	Madsen, B.M., and Raup, O.B. 1988.	Characteristics of the boundary between the Castile and Salado formations near the western edge of the Delaware Basin, southeastern New Mexico. New Mexico Geology, Vol. 10, No. 1, pp. 1-5, 9.
417.	Maiti, T.C., M.R. Smith, and J.C. Laul. 1989.	Colloid Formation Study of U, Th, Ra, Pb, Po, Sr, Rb, and Cs in Briny (High Ionic Strength) Groundwaters: Analog Study for Waste Disposal, Nuclear Technology. Vol. 84, no. 1, 82-87.
418.	Mallick, T. 1994.	Personal Memorandum to J. Iacovino titled WIPP Magnetic Markers.
419.	Marietta, M.G., S.G. Bertram-Howery, D. R. Anderson, K.F. Brinster, R.V. Guzowski, H. Iuzzolino, and R. P. Rechar. 1989.	Performance Assessment Methodology Demonstration: Methodology development for Evaluating Compliance With EPA 40 CFR Part 191, Subpart B, for the Waste Isolation Pilot Plant. SAND89-2027. Albuquerque, NM, Sandia National Laboratories.
420.	Martell, a.e., and Smith, R.M., 1977.	Critical Stability Constants. Vol. 3: Other Organic Ligands. Plenum Publishing Corp, New York, NY.
421.	Martell, Arthur. E, and Robert M. Smith. 1982.	Critical Stability Constants, Volume 5: Other Organic Ligands, Plenum Press, New York.
422.	Martinot, L. and Fuger, J. 1985.	"The Actinides" in Bard, A.J., Parsons, R. and Jordan, J. eds., Standard Potentials in Aqueous Solution, Marcel Dekker, New York, pp. 631-674.
423.	Matalucci, R.V. 1982.	Simulated-Waste Experiments Planned for the Waste Isolation Pilot Plant-WIPP. SAND82-0547. Albuquerque, NM, Sandia National Laboratories.
424.	Mavor, M.J., and T.L. Logan. 1994.	Recent Advances in Coal Gas-Well Openhole Well Completion Technology. JPT, July 1994. pp. 587-593.
425.	Mayer, G., Jacobs, F., and Wittmann, F.H. 1992.	"Experimental Determination and Numerical Simulation of the Permeability of Cementitious Materials," Nuclear Engineering and Design. Vol. 138, no. 2, 171-177.
426.	McCarthy, J.F., and J.M. Zachara. 1989.	Subsurface Transport of Contaminants, Environmental Science and Technology, Vol. 23., no. 5, 496-502.

Ref. #	AUTHOR(s)	REFERENCE
445.	Mualem, Y. 1976.	A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media. Water Resources Research. Vol. 12, no. 3, 513-522.
446.	Muehlberger, W.R., R.C. Belcher, and L.K. Goetz, 1978.	Quaternary Faulting in Trans-Pecos Texas, Geology, Vol. 6, No. 6, pp. 337-340.
447.	Murphy, John N. and H.F. Parkinson. 1988.	<i>Underground Mine Communications</i> , Proceedings of the IEEE, Vol. 66, No. 1, January 1978.
448.	Myers. D.R., and Duranceau, D.A. 1994.	"Prototype Hanford Surface Barrier: Design Basis Document" BHI-00007. Bechtel Hanford, Inc., Richland, WA.
449.	NAGRA, 1985.	Nuclear Waste Management in Switzerland: Feasibility Study and Safety Analyses (Project Gewähr, 1985), NAGRA Project Report NGB 85-09 (English Summary), Wettingen, Switzerland.
450.	Nash, K.L. and Choppin, G.R. 1980.	Interaction of humic and fulvic acids with Th(IV), Journal of Inorganic Nuclear Chemistry. Vol. 42, 1045-1050.
451.	National Academy of Sciences-National Research Council (NAS-NRC), 1957.	The Disposal of Radioactive Waste on Land: A Report of the Committee on Waste Disposal, Division of Earth Sciences, Publication 519, National Academy of Sciences, Washington, D.C..
452.	National Institute of Science and Technology, 1996.	Standard Reference Materials Catalog, 1995-1996. 25-38.
453.	Naunkovic, S. 1986.	Remote Control of Mining Machinery By Means of Radio Waves, JUREMA, Yugoslavia, 1986. (Abstract Only).
454.	Neck, V., Kim, J.I. and Kanellakopoulos, B. 1992.	Solubility and Hydrolysis behavior of Neptunium(V), Radiochimica Acta. v. 56, p. 25.
455.	Neck, V., W. Runde, and J.I Kim. 1995.	"Solid-Liquid Equilibria of Np(V) in Carbonate Solutions at Different Ionic Strengths: II," Journal of Alloys and Compounds. Vol. 225, 295-302.
456.	Neill, R.H., Channell, J.K., Chaturvedi, L., Little, M.S., Rehfeldt, K., and Spiegler, P. 1983.	Evaluation of the Suitability of the WIPP Site. EEG-23. Environmental Evaluation Group, Santa Fe, NM.
457.	Neternieks, I. 1982.	The Movement of a Redox Front Downstream From a Repository for Nuclear Waste, KBS Report TR 82-16.
458.	Neuman, S.P. 1980.	Adjoint-State Finite Element Equations for Parameter Estimation, paper presented at Third International Conference on Finite Elements in Water Resources, School of Eng, Univ. of Miss., Oxford, May 19-23, 1980. 2:66 through 2:75.
459.	New Mexico Administrative Code (NMAC).	20 NMAC 4.1 Subpart V, §264.13. 20 NMAC 4.1 Subpart VIII, §268.35(d).
460.	New Mexico Bureau of Mines and Mineral Resources (NMBMMR). 1995.	FINAL REPORT Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site, Vol. 1-4, March 31, 1995
461.	New Mexico Junior College, 1995.	Analytical Study of an Inadvertent Intrusion of the WIPP Site, Hobbs, New Mexico.
462.	New Mexico Oil Conservation Commission (NMOCC), 1988.	Order R-111-P, Oil Conservation Division, April 1, 1988.

Ref. #	AUTHOR(s)	REFERENCE
479.	Novak, C.F. and R.C. Moore 1996.	Estimates of Dissolved Concentrations for +III, +IV, +V, and +VI Actinides in Salado and Castile Brine, SNL Tech Memo, March 28, 1996. (Copy on file in the Sandia WIPP Central File A: WBS 1.2.0.7.1;WBS1.1.10.1.1: WPO# 35835.)
480.	Novak, C.F., R.C. Moore, and R. Vann Bynum. 1996.	Prediction of Dissolved Concentrations for +III, +IV, +V, and +VI Actinides in Salado and Castile Brine, Sandia Technical Memorandum, Sandia National Laboratories, Albuquerque, NM.
481.	Novak, C.F., R.C. Moore, and R. Vann Bynum. 1996.	Prediction of Dissolved Actinide Concentrations in Concentrated Electrolyte Solutions: A Conceptual Model and Modle Results for the Waste Isolation Pilot Plant (WIPP), in Proceedings of the International Conference on Deep Geological Disposal of Radioactive Waste, September 16-19, 1996. Winnipeg, Manitoba, Canada.
482.	Nowak, E.J., J.R. Tillerson, and T.M. Torres, 1990.	Initial Reference Seal System Design: Waste Isolation Pilot Plant, SAND90-0355, Albuquerque, NM, Sandia National Laboratories.
483.	NRC (U.S. Nuclear Regulatory Commission) 1973.	Design Spectra for Seismic Design of Nuclear Power Plants, Revision 1. Regulatory Guide 1.60, December 1973.
484.	NRC (U.S. Nuclear Regulatory Commission), 1988.	Peer Review for High-Level Nuclear Waste repositories,NUREG-1297, February 1988, Division of High-Level Nuclear Waste Management, Office of Nuclear Material Safety.
485.	NRC (U.S. Nuclear Regulatory Commission), 1988.	Qualification of Existing Data for High-Level Nuclear Waste Repositories,NUREG-1298, February 1988, Division of High-Level Nuclear Waste Management, Office of Nuclear Material Safety and Safeguards, Washington, D.C.
486.	Nuttli, O.W. 1973.	State-of-The-Art for Assessing Earthquake Hazards to the United States: Report One, Design Earthquakes for the Central United States. Miscellaneous Paper S-73-1, pp. 1-45. U.S. Army Waterways Experiment Station, Vicksburg, MS.
487.	Nyhan, J.W. Drennon, B.J., Abeele, W.V., Wheeler, M.L., Purtymun, W.D., Trujillo, G., Herrera, W.J., and Booth, J.W. 1985.	"Distribution of Plutonium and Americium Beneath a 33-yr-old Liquid Waste Disposal Site," Journal of Environmental Quality. Vol. 14, no. 4, 501-509.
488.	OECD Nuclear Energy Agency. 1992.	Systematic Approaches to Scenario Development. Paris: OECD/NEA. NWM Library NNA.920610.0027
489.	ORNL (Oak Ridge National Laboratory). 1973.	Site Selection Factors for the Embedded Salt Pilot Plant. ORNL-TM-4219. Oak Ridge National Laboratory, Oak Ridge, TN.
490.	Palmer, A.R. 1983.	The Decade of North American Geology 1983 Geologic Time Scale. Geology, Vol. 11, pp. 503-504.
491.	Parker, J.C., R.J. Lenhard, and T. Kuppasamy, 1987.	A Parametric Model for Constitutive Properties Governing Multiphase Flow in Porous Media, Water Resources Research, Vol. 23, No. 4, pp. 618-824.
492.	Papenguth, H.W. 1996.	H. W. Papenguth to Christine T. Stockman: "Parameter Record Package for Colloidal Actinide Source Term Parameters" May 7, 1996: Attachment A: Rationale for Definition of Parameter Values for Actinide Intrinsic Colloids." WPO# 35852. (Section WCA.8.5)
493.	Papenguth, H.W. 1996.	H. W. Papenguth to Christine T. Stockman: "Parameter Record Package for Colloidal Actinide Source Term Parameters" May 7, 1996: Attachment A: Rationale for Definition of Parameter Values for Humic Substances." WPO# 35855. (Section WCA.8.7)
494.	Papenguth, H.W. 1996.	H. W. Papenguth to Christine T. Stockman: "Parameter Record Package for Colloidal Actinide Source

Ref. #	AUTHOR(s)	REFERENCE
513.	Powers, D.W., 1993.	Background Report on Subsidence Studies for the Potash Mines and WIPP Site Area.
514.	Powers, D.W., and Holt, R.M., 1995.	Regional Geological Processes Affecting Rustler Hydrogeology, Westinghouse Electric Corp, Carlsbad, NM.
515.	Powers, D.W. et al., eds.	<p>Geological and Hydrological Studies of Evaporites in the Northern Delaware Basin for the Waste Isolation Pilot Plant (WIPP), New Mexico, 1990 Annual Meeting, Dallas, TX, October 29 - November 1, 1990, GSA Field Trip #14. Dallas Geological Society, Dallas, TX.</p> <p style="text-align: center;">Articles</p> <p>Beauheim, R.L., and R.M. Holt, 1990. Hydrogeology of the WIPP Site, pp. 131-179.</p> <p>Holt, R.M., and Powers, D.W. 1990. Halite Sequences within the Late Permian Salado Formation in the Vicinity of the Waste Isolation Pilot Plant. pp. 45-78.</p> <p>Powers, D.W., and R.M. Holt, 1990. Sedimentology of the Rustler Formation near the Waste Isolation Pilot Plant (WIPP) Site, Mexico, pp. 79-106.</p> <p>Powers, D.W., and LeMone, D.V. 1990. A Summary of Ochoan Stratigraphy of the Western and Northern Delaware Basin., pp. 27-32.</p>
516.	Powers, D.W., J.M. Sigda, and R.M. Holt. 1996.	"Probability of Intercepting a Pressurized Brine Reservoir Under the WIPP." Unpublished report, July 10, 1996. Albuquerque, NM: Sandia National Laboratories. (Copy on file in the SWCF).
517.	Pratt, H.R., Stephenson, D.E., Zandt, G., Bouchon, M., and Hustrulik, W.A. 1979.	Earthquake Damage to Underground Facilities (Proceedings of the 1979 RETC, Vol. 1, AIME, Littleton, Colorado.)
518.	Pruess, K. 1991.	TOUGH2 - A General Purpose Numerical Simulator for Multiphase Fluid and Heat Flow. LBL-29400. Berkeley, CA: Lawrence Berkeley Laboratory.
519.	Pryke, D.C., and J.H. Rees. 1987.	Understanding the Behavior of the Actinides Under Disposal Conditions: a Comparison between Calculated and Experimental Solubilities, Radiochimica Acta, Vol. 51, 27.
520.	Pusch, R., Borgesson, L., and Ranquist, G. 1987	Final Report of the Borehole, Shaft, and Tunnel Sealing Test--Volume I: Borehole Plugging, SKB 87-01. Stockholm, Sweden: Swedish Nuclear Fuel and Waste Management Co.
521.	Rai, D., and J.L. Swanson. 1981.	Properties of Plutonium(IV) Polymer of Environmental Importance, Nuclear Technology, Vol. 54, no. 1, 107-111.
522.	Rai, D., and R.G. Strickert. 1980.	Chemical Aspects of Medium and Long-term Radioactive Waste Disposal, Trans. Am. Nuclear Soc. and Eur. Nuclear Soc. Vol. 35, 185.
523.	Rai, D., A.R. Felmy, and R.W. Fulton.	"Nd ³⁺ and Am ³⁺ Ion Interactions with Sulfate Ion," Journal of Solution Chemistry. Vol. 24, no. 9, 879-895.
524.	Rai, D., R.G. Strickert, and G.L. McVay. 1982.	Neptunium Concentration in Solutions Containing Actinide-Doped Glass, Nuclear Technology, Vol. 58, 69.
525.	Rai, D., R.J. Serne, and Moore. 1980.	Solubility of Plutonium Compounds and their behavior in Soils, Soil Science Society of America Journal, Vol. 44, 490.
526.	RamaRao, B.S., and M. Reeves. 1990.	Theory and Verification for the GRASP II Code for Adjoint-Sensitivity Analysis of Steady-State and Transient Groundwater Flow. Contractor Rep. SAND89-2143J. Albuquerque, NM: Sandia National

Ref. #	AUTHOR(s)	REFERENCE
544.	Refait, Ph. and Genin, J.-M.R. 1994.	The Transformation of Chloride-containing Green Rust One into Sulphated Green Rust Two by Oxidation in Mixed Cl and SO ₄ ²⁻ Aqueous Media, Corrosion Science, Vol, 36, 55-65.
545.	Register, J.K. 1981	Rubidium-strontium and related studies of the Salado formation, southeastern New Mexico. SAND81-7072. Albuquerque, NM: Sandia National Laboratories.
546.	Richter, C.F. 1958.	Elementary Seismology. W.H. Freeman & Co., San Francisco, CA. Lib of Con # 58-5970.
547.	Richardson, G.B. 1904.	Report of a reconnaissance of trans-Pecos, Texas north of the Texas and Pacific Railway. Texas University Bulletin 23, pp. 119.
548.	Richardson, R.G. 1996.	Personal Communication between R. G. Richardson, Westinghouse Electric Corporation, Carlsbad, NM and Barbara Graves, John Hart and Associates, P. A., June 6, 1996.
549.	Richardson, R.G. 1996.	Personal Communication between R. G. Richardson, Westinghouse Electric Corporation, Carlsbad, NM and William A Trippet II, John Hart and Associates, P. A., January 8, 1996.
550.	Roberts, D. and the Westinghouse Electric Corporation, 1996.	Personal communication, J. Johns, Westinghouse and Derald Roberts, Drilling Superintendent, Santa Fe Energy Corporation, Midland, TX, April 23, 1996.
551.	Robinson, J.Q., and Powers, D.W. 1987.	A Clastic Deposit Within the Lower Castile Formation, Western Delaware Basin, New Mexico. El Paso Geological Society Guidebook, Vol. 18, pp. 69-79.
552.	Robinson, R.A., and R.H. Stokes. 1959.	Electrolyte Solutions, The Measurement and Interpretation of Conductance, Chemical Potential, and Diffusion in Solutions of Simple Electrolytes, 2nd ed (revised). London, England: Butterworths.
553.	Robinson, T.W., and W.B. Lang, 1938.	Geology and Ground-Water Conditions of the Pecos River Valley in the Vicinity of Laguna Grande de la Sal, New Mexico, With Special Reference to the Salt Content of the River Water, New Mexico State Engineer 12th-13th Biennial Reports 1934-1938, Santa Fe, NM, State Engineer, pp. 77-100.
554.	Rogers, A.M., and Malkiel, A. 1978.	A Study of Earthquakes in the Permian Basin, Texas-New Mexico [Draft]. Open-File Report. U.S. Geological Survey
555.	Rosholt, J.N., and McKinney, C.R. 1980.	Uranium Series Disequilibrium Investigations Related to the WIPP Site, New Mexico, Part II Uranium Trend Dating of Surficial Deposits and Gypsum Spring Deposit Near WIPP Site, New Mexico. Open-File Report 80-879. U.S. Geological Survey, Denver, CO.
556.	Ross, S. and I.D. Morrison. 1988.	Colloidal Systems and Interfaces, New York, NY: John Wiley & Sons.
557.	Runde, W. and Kim, J.I. 1994.	Untersuchungen der Übertragbarkeit von Labordaten natürliche Verhältnisse. Chemisches Verhalten von drei- und fünf wertigen Americium in salinen NaCl-Lösungen, Report RCM-01094, Institut für Radiochemia, Technische Universität München.
558.	Ruskauff, Greg. 1996.	Memorandum to Martin Teirney, Re: Culebra Transmissivity Field Index, March 13, 1996. WPO 35193.
559.	Sagoe-Crentsil, K.K., and F.P. Glasser. 1993.	Green Rust, Iron Solubility and the Role of Chloride in the Corrosion of Steel at High pH, Cement and Concrete Research, Vol, 23, 785-791.
560.	Sanchez, L.C., and H.R. Trelue. 1996.	Estimation of Maximum RH-TRU Thermal Heat Load for WIPP, January 17, 1996. (Section WCA8.16).
561.	Sandia National Laboratories. 1979.	Summary of Research and Development Activities in Support of Waste acceptance Criteria for WIPP. SAND79-1305. Albuquerque, NM, Sandia National Laboratories.

Ref. #	AUTHOR (s)	REFERENCE
580.	Schilling, J.H., ed.	Isochron/West The bulletin of Isotopic Geochronology, No. 29, December 1980. Articles Brookins, D.G. 1980. Polyhalite K-Ar radiometric ages from southeastern New Mexico, 29-31. Register, J.K., and D.G. Brookins. 1980. Rb-Sr Isochron Age of Evaporite Minerals from the Salado Formation (Late Permian), Southeastern New Mexico, 39-42.
581.	Schnitzer, M. and S.I.M. Skinner. 1967.	Organo-Metallic Interactions in Soils: 7 Solubility Constants of Pb ⁺⁺ , Ni ⁺⁺ , Mn ⁺⁺ , Co ⁺⁺ , Ca ⁺⁺ , and Mg ⁺⁺ -Fulvic Acid Complexes, Soil Science, Vol. 103, no. 4, 247-252.
582.	Scott, L. and the Westinghouse Electric Corporation, 1996.	Personal Communication, J. Johns, Westinghouse and Larry Scott, President, Lynx Petroleum Company, Hobbs, NM, April 24, 1996.
583.	Serne, R.J. 1992.	"Current Adsorption Models and Open Issues Pertaining to Performance Assessment." In Proceedings of the DOE/Yucca Mountain Site Characterization Project Radionuclide Adsorption Workshop at Los Alamos National Laboratory, September 11-12, 1990. Comp. J.A. Canepa. LA-12325-C. Los Alamos National Laboratory, Los Alamos, NM. 43-74.
584.	Serne, R.J., D. Rai, M.J. Mason, and M. A. Molecke. 1977.	Batch Kd Measurements of Nuclides to Estimate Migration Potential at the Proposed Waste Isolation Pilot Plant in New Mexico. PNL-2448. Richland, WA: Batelle Pacific Northwest Laboratories.
585.	Sewards, T., 1991.	Characterization of Fracture Surfaces in Dolomite Rock, Culebra Dolomite Member, Rustler Formation, SAND90-7019, Albuquerque, NM, Sandia National Laboratories.
586.	Sewards, T., A. Brearly, R. Glenn, I.D.R. Mackinnon, and M.D. Siegel, 1992.	Nature and Genesis of Clay Minerals of the Rustler Formation in the Vicinity of the Waste Isolation Pilot Plant in Southeastern New Mexico, SAND90-2569, Albuquerque, NM, Sandia National Laboratories.
587.	Sewards, T., M.L. Williams, and K. Keil, 1991.	Mineralogy of the Culebra Dolomite Member of the Rustler Formation, SAND90-7008, Albuquerque, NM, Sandia National Laboratories.
588.	Siegel, M.D. 1996.	Solubility parameters for use in the CCA NUTS and GRIDFLOW calculations. SNL Technical memorandum dated 29 March 1996 to Martin S. Tierney. (Copy on file in the Sandia WIPP Central File A:WBS 1.2.0.7.1;WBS 1.1.10.61: WPO #35835)
589.	Siegel, M.D., J.O. Leckie, S.W. Park, S.L. Phillips, and T. Sewards, 1990.	Studies of Radionuclide Sorption by Clays in the Culebra Dolomite at the Waste Isolation Pilot Plant Site, Southeastern New Mexico, SAND89-2387, Albuquerque, NM, Sandia National Laboratories.
590.	Siegel, M.D., Lambert, S.J. and Robinson, K.L. eds. 1991.	Hydrochemical Studies of the Rustler Formation and Related Rocks in the WIPP Area, Southeastern New Mexico, SAND88-7096, Albuquerque, NM, Sandia National Laboratories. WPO 25624.
591.	Siegel, M.D., Lambert, S.J. and Robinson, K.L. eds. 1991.	Hydrogeochemical Studies of the Rustler Formation and Related Rocks in the WIPP Area, Southeastern New Mexico, SAND88-0196, Albuquerque, NM, Sandia National Laboratories.
592.	Silva, M. 1994.	Implications of the presence of Petroleum resources on the integrity of the WIPP EEG-55, DOE/AL/58309-55
593.	Sipes, Williamson & Aycock, Inc., 1976.	Hydrocarbon Evaluation, Proposed Southeastern New Mexico Radioactive Material Storage Site, Eddy County, New Mexico, SAND77-7033, Albuquerque, NM, Sandia National Laboratories, Vols. 1-2.
594.	Skokan, C.K., Pfeifer, M.C., Keller, G.V., and Andersen, H.T. 1989.	Studies of Electrical and Electromagnetic Methods for Characterizing Salt Properties at the WIPP Site, New Mexico. SAND87-7174. Albuquerque, NM: Sandia National Laboratories. WPO 24033.

Ref. #	AUTHOR(s)	REFERENCE
608.	Stensrud, W.A., T.F. Dale, P.S. Domski, J.B. Palmer, R.M. Roberts, M.D. Fort, and G.J. Saulnier, Jr. 1992.	Waste Isolation Pilot Plant Salado Hydrology Program Data Report #2. SAND92-7072. Albuquerque, NM: Sandia National Laboratories.
609.	Stephens, D.B., Unruh, M., Havlena, J., Knowlton, R.G., Jr., Mattson, E., and Cox, W. 1988.	"Vadose Zone Characterization of Low-Permeability Sediments Using Field Permeameters," Ground Water Monitoring Review. Vol. 8, no. 2, 59-66.
610.	Stockman, Christine. 1996.	Memo to Martin Tierney. RE: Implementation of Chemistry Parameters in PA. April 16, 1996. WPO 37536.
611.	Stoelzel, D.M., and O'Brien, D.G. 1996.	The Effects of Salt Water Disposal and Waterflooding on WIPP. Summary Memo of Record for NS-7a. Sandia National Laboratories, Albuquerque, NM. WPO 40837.
612.	Stormont, J.C., 1988.	Preliminary Seal Design Evaluation for the Waste Isolation Pilot Plant, SAND87-3083, Albuquerque, NM, Sandia National Laboratories.
613.	Storz, L. 1996.	Estimate of the Amount of Ca(OH) ₂ Contained in the Portland Cement Fraction of the Waste for Disposal in the WIPP, Memorandum to Yifeng Wang. (Copy on file in Sandia WIPP Central File A: WBS 1.1.09.1.1.)
614.	Streeter, V.L. 1958.	Fluid Mechanics. 2nd ed. New York, NY: McGraw-Hill.
615.	Stroes-Gascoyne, S. and J.M. West. 1994.	Microbial Issues Pertaining to the Canadian Concept for the Disposal Of Nuclear Fuel Waste, AECL Report no. AECL-10808, COG-93-54. 39pp.
616.	Stuhenberg, D., and C. Zhang. 1995.	Results of Experiments on the Compaction and Permeability Behavior of Crushed Salt. Proceedings of the Fifth International Conference on Radioactive Waste Management and Environmental Remediation, Volume 1, Berlin, Germany.
617.	Stumm, W. 1992.	Chemistry of the Solid-Water Interface, New York, NY, John Wiley & Sons, Inc.
618.	Stumm, W. 1993.	Aquatic Colloids as Chemical Reactants: Surface Structure and Reactivity, Colloids in the Aquatic Environment. Ed. T.F. Tadros and J. Gregory, New York, NY: Elsevier Applied Science. (Reprinted from Colloids and Surfaces. Vol. 73, 1-18).
619.	Sutherland, H.J., and Munson. 1983.	Subsidence Predictions for High Extraction Mining Using Complementary Influence Functions, SAND82-2949, 1983.
620.	Swift, P.N., B.L. Baker, K. Economy, J.W. Garner, J.C. Helton, and D.K. Rudeen. 1994.	Incorporating Long-Term Climatic Change in Performance Assessment for the Waste Isolation Pilot Plant. SAND93-2266. Albuquerque, NM: Sandia National Laboratories.
621.	Sykes, P.F., J.J. Wilson, and R.W. Andrews. 1985.	Sensitivity Analysis for steady state groundwater flow using adjoint operators, Water Resour. Res., 21(3), 359-371, 1985.
622.	Telander, M.R., and R.E. Westerman. 1993.	Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments. SAND92-7347. Albuquerque, NM, Sandia National Laboratories.
623.	Telford, W.M., Geldart, L.P., Sheriff, R.E. and Keys, D.A. 1976.	Applied Geophysics. Cambridge University Press, Cambridge.

Ref. #	AUTHOR(s)	REFERENCE
642.	van der Lee, J., G. de Marsily, and E. Ledoux. 1993.	Are Colloids Important for Transport Rate Assessment of Radionuclides? In High Level Radioactive Waste Management, Proceedings of the Fourth Annual International Conference; Las Vegas, Nevada, 646-652. (CONF930408)
643.	van der Lee, J., Ledoux, E., and de Marsily, G. 1994.	"Microscopic Description of Colloid Transport in Fractured Media or Porous Media," Transport and Reactive Processes in Aquifers; Proceedings of the IAHR/AIRH Symposium, Zurich, Switzerland, April 11-15, 1994. Eds. Th. Dracos and F. Stauffer. A.A. Balkema, Brookfield, VT. 349-355.
644.	van Genuchten, M. Th. 1980.	"A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils," Soil Science Society of America Journal/ Vol. 44, no. 5, 892-898.
645.	van Genuchten, M. Th., and Nielsen, D.R. 1985.	"On Describing and Predicting the Hydraulic Properties of Unsaturated Soils," Annales Geophysicae. Vol. 3, no. 5, 615-628.
646.	Van Pelt, R.S. 1995.	"Permeability Estimates of MGFT08 and MGFT09." SNL Technical Memorandum to M.K. Knowles. Contained in SWCF Record Package, "Small-Scale Seals Performance Test: Series A Post-Mortem," WPO 39631. November 20, 1995.
647.	Vaughn, P., J. Bean, J. Garner, M. Lord, R. MacKinnon, D. McArthur, J. Schreiber, and A. Shinta. 1995.	FEPs Screening Analysis DR2, DR3, DR6, DR7, and S6. Record Package submitted to SWCF-A:1.1.6.3:PA:QA:TSK:DR2, DR3,DR6,DR7
648.	Vaughn, P., Lord, M., and MacKinnon, R. 1995.	"DR-6: Brine Puddling in the Repository due to Heterogeneities." Summary Memo of Record to D.R. Anderson, December 21, 1995. SWCF-A:1.1.6.3. Sandia National Laboratories, Albuquerque, NM. WPO 30795.
649.	Vaughn, P., Lord, M., and MacKinnon, R. 1995.	"DR-7: Permeability Varying with Porosity in Closure Regions." Summary Memo of Record to D.R. Anderson, December 21, 1995. SWCF-A:1.1.6.3. Sandia National Laboratories, Albuquerque, NM. WPO 30796.
650.	Vaughn, P., Lord, M., and MacKinnon, R. 1995.	DR3: Dynamic Closure of the North End and Hallways." Summary Memorandum of Record to D.R. Anderson, September 28, 1995. SWCF-A:1.1.6.3. Sandia National Laboratories, Albuquerque, NM. WPO 30798.
651.	Vaughn, P., Lord, M., and MacKinnon, R. 1995.	"GG-1: Radiolysis of Brine." Summary Memo of Record to D.R. Anderson, October 10, 1995. SWCF-A:1.1.6.3. Sandia National Laboratories, Albuquerque, NM. WPO 30791.
652.	Vaughn, P., Lord, M., Garner, J., and MacKinnon, R. 1995.	Radiolysis of Brine. Errata to Summary Memo of Record GG-1, SWCF-A:1.1.6.3:PA:QA:TSK:GG1,S7, December 21, 1995. Sandia National Laboratories, Albuquerque, NM. WPO 30786.
653.	Vaughn, P., Lord, M., and MacKinnon, R. 1995.	DR-2: Capillary Action (Wicking) within the Waste Materials." Summary Memo of Record to D.R. Anderson, December 21, 1995. SWCF-A:1.1.6.3. Sandia National Laboratories, Albuquerque, NM. WPO 30793.
654.	Vaughn, P., Lord, M., and MacKinnon, R. 1995.	S-6: Dynamic Alteration of the DRZ/Transition Zone: Summary Memo of Record to D.R. Anderson, September 28, 1995. SWCF-A (WPO #30798). Sandia National Laboratories, Albuquerque, NM. See Ref # 650
655.	Vaughn, P.L. 1996.	Impacts of Using Only H ₂ on Repository Flow and Pressure. Response to Peer Review, May 21, 1996.
656.	Vaughn, Palmer. 1996.	Memo to Martin Tierney. RE: WAS_AREA and REPOSIT/SAT_RBRN Distribution, February 13, 1996. WPO 34902.

Ref. #	AUTHOR(s)	REFERENCE
674.	Wang, Y., and L.H. Brush. 1996.	"Modify the Stoichiometry Factor γ in BRAGFLO to Include the Effect MgO Added to WIPP Repository as Backfill." Unpublished memorandum to M.S. Tierney, February 23, 1996. Albuquerque, NM: Sandia National Laboratories.
675.	Ward, D.S., M. Reeves, and L.E. Duda. 1984.	Verification and field comparison of the Sandia Waste Isolation Flow and Transport Model (SWIFT), Rep SAND83-1154, Sandia Natl. Lab., Albuquerque, NM, 1984 (Also available as NUREGICR-3316 from Nucl. Regul. Comm., Rockville, MD.)
676.	Warrick, R. and J. Oerlemans. 1990.	Sea Level Rise, Climate Change: The IPCC Scientific Assessment. Eds. J.T. Houghton, G.J. Jenkins, and J.J. Ephraums, Sweden Intergovernmental Panel on Climate Change. 261-285.
677.	Waste Isolation Division (WID), 1991.	VOC Monitoring Plan. WP 12-6, Rev.1. January 21, 1994. Waste Isolation Division, Carlsbad, NM.
678.	Waste Isolation Division (WID), 1994.	WP 12-7, Volatile Organic Compounds Monitoring Quality Assurance Project Plan, Rev. 2, January 21, 1994. This document is included with Ref # 677.
679.	Watkins, D. 1996.	Estimate of Cement Content in TRU Solidified Waste Forms Schedules for Disposal in WIPP, Memorandum to Les Shepard. (Section WCA.8.13)
680.	Wawersik, W.R., and C.M. Stone. 1989.	"A Characterization of Pressure Records in Inelastic Rock Demonstrated by Hydraulic Fracturing Experiments in Salt," <i>Int. J. Rock Mech. Min. Sci. & Geomech. Abstr.</i> , Vol. 26, 613-627.
681.	Weart, W.D., 1983.	Summary Evaluation of the Waste Isolation Pilot Plant (WIPP) Site Suitability, SAND83-0450, Albuquerque, NM, Sandia National Laboratories.
682.	Weatherby, J.R., W.T. Brown, and B.M. Butcher. 1991.	The Closure of WIPP Disposal Rooms Filled with various Waste and Backfill Combinations. Rock Mechanics as a Multidisciplinary Science, Proceedings of the 32nd U.S. Symposium, University of Oklahoma, Norman, OK, July 10-12, 1991. Ed. J.C. Roegiers. SAND90-2399C. Brookfield, VT: A.A. Balkema. 919-928.
683.	Webb, S. 1995.	"DR-1:3D Room Flow Model with Dip." Planning Memo of Record to D.R. Anderson, May 30, 1995. SWCF-A:1.1.6.3. Sandia National Laboratories, Albuquerque, NM. WPO 22494.
684.	WEC. 1994.	Backfill Engineering Analysis Report, Waste Isolation Pilot Plant. Carlsbad, NM: Westinghouse Electric Corporation.
685.	Weiner, R. 1996.	Documentation Package for: oxidation state distribution of actinides in the repository. SNL Technical memorandum dated 27 March 1996 to SWCF-A: Records Center, SWCF-A: WBS 1.1.10.1.1:PDD: QA: Dissolved Species: Oxidation State Distribution: Actinides: OX3: OX4: OX5: OX6 (WPO# 35194).
686.	Weiner, R. 1996.	Memorandum to C.F. Novak, Subject: Dissolved Ligand Concentration. March 27, 1996. Sandia National Laboratories, Albuquerque, NM.
687.	Weiner, Ruth F., Hobart, D.E., Tait, C.D., and Clark, D.L. 1996.	Analysis of Actinide Oxidation States in the WIPP, WBS 1.1.10.1.1. WPO 35194.
688.	Weitzberg, A. 1982.	Building on Existing Institutions to Perpetuate Knowledge of Waste Repositories. ONWI-379 UC-70.

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-G: DEPARTMENT OF ENERGY'S COMPLIANCE CERTIFICATION
APPLICATION FOR THE WASTE ISOLATION PILOT PLANT**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
-----	------------------------	---	---------------------

II-G-2	11/18/96	COMPLIANCE APPLICATION GUIDANCE (CAG) CHECKLIST for the Waste Isolation Pilot Plant	11/96
II-G-3	12/23/96	QA packages for 13 PA Codes (supplemental Information Supporting the DOE/WIPP Compliance Certification Application	11/96
	Vol I	ALGEBRACDB SRC - Software Requirements Checklist RD & VVP - Request Document & Verification and Validation Plan VD - Validation Document, Version 1.00 ID - Implementation Document for Version 2.35 BRAGFLO UM - User's Manual for BRAGFLO, Version 4.00	

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-G: DEPARTMENT OF ENERGY'S COMPLIANCE CERTIFICATION
APPLICATION FOR THE WASTE ISOLATION PILOT PLANT**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
Vol. 7		GRASP-INV UM - User's Manual - Version 1.00 for GRASP-INV (Version 2.01) RD&VVP - Requirements Document and Verification and Validation Plan - Version 1.00 for GRASP-INV (Version 2.01) VD-Validation Document- Version 1.00 for GRASP-INV (Version 2.01)	
Vol. 8		GRASP-INV (continued) ID-Implementation Document-Version 1.00 for GRASP-INV (Version 2.01) LHS UM - User's Manual for LHS Version 2.41, Version 1.00 RD&VV - Requirements Document & Verification and Validation - Version 1.00 for LHS (Version 2.40 VD - Validation Document - Version 1.00 for LHS (Version 2.40 ID - Implementation Document - Version 1.00 for LHS (Version 2.41)	
Vol. 9		NUTS UM - User's Manual - Version 1.00 for NUTS (Version 2.02) RD&VVP - Requirements Document & Verification and Validation - Version 1.00 for NUTS (Version 2.02)	
Vol. 10		NUTS (continued) VD - Validation Document - Version 1.00 for NUS (Version 2.02) ID - Implementation Document - Version 1.1 for NUTS (Version 2.02)	
Vol. 11		PANEL UM - User's Manual - Version 1.00 for PANEL (Version 3.60) RD&VVP - Requirements Document & Verification and Validation for PANEL (Version 3.60 VD - Validation Document for PANEL (Version 3.60) ID - Implementation Document - Version 1.0 for PANEL (Version 3.60) SANTOS QAD Quality Assurance Document - Version 1.00 for SANTOS (Version 2.0.0) V&QD - Verification and Qualification Document	

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-G: DEPARTMENT OF ENERGY'S COMPLIANCE CERTIFICATION
APPLICATION FOR THE WASTE ISOLATION PILOT PLANT**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-G-11	01/15/97	Analysis Package of the Culebra Flow and Transport Calculations (Task 3) of the Performance Assessment Analysis - WPO #40516, Supporting the Compliance Certification Application Analysis - Plan 019	12/11/96
II-G-12	01/15/97	Waste Isolation Pilot Plant - Conceptual Models Supplementary Peer Review Report	12/96
II-G-13	01/15/97	Waste Isolation Pilot Plant - Engineered Systems Data Qualification Supplementary Peer Review Report	12/96
II-G-14	01/15/97	Waste Isolation Pilot Plant - Waste Characterization Analysis Supplementary Peer Review Report	12/96
II-G-15	01/15/97	Waste Isolation Pilot Plant - Passive Institutional Controls Supplementary Peer Review Report	12/96
II-G-16	02/06/97	Effectiveness of Passive Institutional Controls in Reducing Inadvertent Human Intrusion into the WIPP, WIPP/CAO-96-3168, Revision 1, November 14, 1996 with Addendum of December 6, 1996 (Transmittal letter filed A-93-02, II-I-05)	11/14/96
II-G-17	3/26/97	Analysis Package for the BRAGFLO Sensitivity Study, WPO#43593, Revision #1, dated 3/11/97, entitled "Sensitivity of Flow, Transport, and Direct Brine Release to Grid Refinement Using the BRAFGFLO and NUTS Computer Models." (This document is filed with transmittal letter, see A-93-02, II-I-16.)	3/11/97
II-G-18	3/26/97	Analysis of Ground Water Travel Times through Calibrated Transmissivity Fields Generated by GRASP-INV, WPO#44199 (Version 2.01) Revision O, March 1997, with Appendix A - TCSTRIP UTILITY CODE VERIFICATION Rev. O, March 1997, and Appendix B - HDSTRIP UTILITY CODE VERIFICATION Rev O, March 1997 (Transmittal letter filed A-93-02, II-I-19).	3/97
II-G-19	5/1/97	Amendments to CAO Peer Review Management Plan and Peer Review Plans for: <ul style="list-style-type: none"> - Engineered Systems, Rev. 1, 6/25/96 - Passive Institutional Controls, Rev. 0, 5/28/96 - Conceptual Models, Rev. 0, 3/3/96 - Waste Characterization, Rev. 0, 6/27/96 	10/30/96

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-G: DEPARTMENT OF ENERGY'S COMPLIANCE CERTIFICATION
APPLICATION FOR THE WASTE ISOLATION PILOT PLANT**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-G-28	8/15/97	Supplemental Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison with the Compliance Certification Application Calculations - WPO#46702	8/8/97
II-G-29	9/4/97	EPA Memo to files E.K. Forinash - Complete Compliance Certification Application	5/22/97
II-G-30	9/4/97	Summary of Uncertainty and Sensitivity Analysis Results for the EPA-Mandated Performance Assessment Verification Test - WPO #46912	8/22/97
II-G-31	9/4/97	CAO-94-1045: Performance Demonstration Program Plan for Nondestructive Assay for the TRU Waste Characterization Program. Revision 1 (Enclosure 2) (Transmittal letter with Enclosure 1 is filed docket A-93-02, II-I-51)	5/97
II-G-32	9/4/97	Information Sheet - How to Obtain Records at the U.S. Department of Energy's Carlsbad Area Office for the Waste Isolation Pilot Plant Compliance Certification Application, 97-006, 8/97	8/97
II-G-33	9/4/97	WPO 46124 April 21, 1997 memorandum from Craig F. Novak to R. Vann Bynum " <i>Calculation of Actinide Solubilities in WIPP SPC and ERDA6 Brines Under MgO Backfill Scenarios Containing Nesquehonite or Solubility-limiting Hydromagnesite as the MgO-CO₃ Phase</i> ".	4/21/97
II-G-34	9/4/97	WPO 46646 June 27, 1997 memorandum from Yifeng Wang and Kurt Larson to Margaret Chu " <i>Estimate Waste Shear Stress for WIPP PA Caving Model</i> "	6/27/97
II-G-35	9/4/97	WPO 46411 July 21, 1997 memorandum from S. Howarth and Palmer Vaughn to Margaret Chu " <i>Changes in Classification of Data Category' Column in the EPA Parameter Database</i> "	7/21/97
II-G-36	9/4/97	WPO 46936 August 5, 1997 memorandum from Yifeng Wang to Margaret CCU " <i>Estimate WIPP Waste Particle Sizes on Expert Elicitation Results: Revision 1</i> "	8/5/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-H: PUBLIC COMMENTS RECEIVED IN RESPONSE TO THE ANPR
DATED NOVEMBER 15, 1996**

NO.	Date Sent to Docket	COMMENTS/ADDRESSEE Title and/or Subject	Date of Document
II-H-01	12/17/96	Walter Gerstle - Comments on WIPP Performance Assessment	12/3/96
II-H-02	12/17/96	Don Hancock for the Southwest Research Information Center - Comments on Completeness of Compliance Certification Application	12/6/96
II-H-03	12/17/96	Roger Y. Anderson - Comments on DOE/CAO 1996-2184	12/2/96
II-H-04	12/23/96	Janet Greenwald, CARD, Lee Lysne, CCNS, Dan Kerlinsky, NMPSR, Don Hancock, SRIC - Comments on Public Hearings	12/13/96
II-H-05	12/23/96	Ltr. Roger Y. Anderson - Correction to the Document filed at II-H- 03	12/2/96
II-H-06	12/23/96	Laura and Sanford Clarke - Comments on Completeness of CCA	12/12/96
II-H-07	12/23/96	Susan Diane - Comments of Completeness of CCA	12/11/96
II-H-08	12/23/96	Erica M. Elliott - Comments on Completeness of CCA	12/10/96
II-H-09	1/6/97	Jean McFarland-Altschuler/Comments on Completeness of CCA	12/13/96
II-H-10	1/6/97	Lindsay Lovejoy/Comments on Completeness of CCA	12/17/96
II-H-11	1/15/97	Lee Lysne/CCNS/Comments on Completeness of CCA	12/10/96
II-H-12	2/14/97	Robert Neill/EEG/Comments on CCA	2/7/97
II-H-13	03/07/97	Ltr/Military Production Network/Maureen Eldredge, Program Director, Comments on Completeness of CCA	2/13/97
II-H-14	03/07/97	Name Illegible, Public Comments on WIPP	1/23/97
II-H-15	03/07/97	Lee Lysne, Margaret Carde - Comments on CCA	2/12/97
II-H-16	03/07/97	Barbara Johnson, Rio Grande Chapter, Sierra Club, Comments on CCA	2/21/97
II-H-17	03/07/97	Transcript of Proceedings of Public Hearings held in: (a) Carlsbad, NM on February 19, 1997	 2/19/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-H: PUBLIC COMMENTS RECEIVED IN RESPONSE TO THE ANPR
DATED NOVEMBER 15, 1996**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-H-31	3/26/97	Ruth F. Weiner Response to Comments Submitted by Rio Grande Chapter of the Sierra Club	3/13/97
II-H-32	3/26/97	Margaret Carde. CCNS Comments on CCA	3/17/97
II-H-33	3/26/97	CARD Comments on the CCA Consists of 9 Papers: 1) "Comments on the DOE CCA, 1996 for the WIPP, NM" 2) "Conceptual Errors on the DOE Model for Groundwater Flow in the Rustler Formation" 3) "Cavernous Zones at the WIPP Site" 4) "Rainwater Recharge at the WIPP Site" 5) "Potential Flow Paths From the WIPP Site to the Accessible Environment" 6) "Breach Scenarios at the WIPP" 7) "Nuclear Transmutation as a means of Reducing the Menace of Plutonium and Radioactive Waste" 8) "WIPP Waste Storage Concerns at the Los Alamos National Laboratory" 9) "Human Error and the Department of Energy"	No Date
II-H-34	4/3/97	Ltr/Deborah Read to/Ramona Trovato/Comments on CCA	3/17/97
II-H-35	4/3/97	Ltr/David Arne Shepard/Comments on CCA	3/17/97
II-H-36	4/3/97	LATE: Ltr/John Paperiello, NRC/Comments on CCA	3/18/97
II-H-37	4/23/97	Ltr/Jennifer Salisbury NM Radioactive Waste Consultation Task Force/Comments on the CCA	3/17/97
II-H-38	4/23/97	Ltr/Don Kimball, SEIS II for WIPP	No Date
II-H-39	4/23/97	Ruth F. Weiner, Ph.D./Comments on CCA from Ruth F. Weiner	3/13/97
II-H-40	5/8/97	Ltr/Don Hancock, Southwest Research and Information Center to/Ramona Trovato/Comments on EPA's Rulemaking Process	4/23/97
II-H-41	6/18/97	LATE: a) Ltr/NRC/Carl J. Paperiello, Director, Office of Nuclear Material Safety and Safeguards W/enclosures: b) Enclosure 1: NRC Policy Issue Paper (SECY-97-073): Comments on ANPR	6/2/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-I: EPA/DOE CORRESPONDENCE AND ACTIVITIES AFTER
PUBLICATION OF THE ANPR DATED NOVEMBER 15, 1996**

NO.	Date Sent to Docket	COMMENTS/ADDRESSEE Title and/or Subject	Date of Document
II-I-01	11/23/96	Ltr from EPA/M. Nichols to DOE/Alvin Alm/Asst Secretary, transmitting comments regarding completeness and technical sufficiency of the Compliance Certification Application	12/19/96
II-I-02	1/29/97	Ltr/G. Dials/DOE/CAO to EPA/R. Trovato, responding to EPA's Letter of December 19, 1996 to DOE/L. Alm requesting additional CCA documentation. Supplemental information for the Compliance Certification Application (CCA) includes the following: <u>Response to EPA Comments, Enclosure 1:</u> a. 194.23(a)(1) Models and Computer Codes b. 194.23(a)(2) Models and Computer Codes c. 194.32(c) Scope of Performance <u>Response to EPA Comments, Enclosure 2</u> a. 194.32(a) Scope of Performance	1/17/97
II-I-03	1/29/97	Ltr / DOE/G. Dials to EPA/R. Trovato - second response package to EPA's letter of December 19, 1996 to DOE/A. Alm. Supplemental Information for the Compliance Certification Application (CCA) includes the following: <u>Response to EPA Comments Enclosure 1</u> a. 194.14(a)(3) Content of Compliance Certification Application b. 194.22(a)(2)(iii) Quality Assurance c. 194.23(a)(3)(i) Models and Computer Codes <u>Response to EPA Comments Enclosure 2</u> a. 194.23(a)(1) Models and Computer Codes b. 194.32(e)(3) Scope of Performance c. 194.33(c)(1) Consideration for drilling events in performance assessment d. 194.53 Consideration of underground sources of drinking water	1/24/97
II-I-04	2/06/97	Ltr/EPA/R. Trovato to DOE/G. Dials, scheduling audit of the Carlsbad Area Office' Quality Assurance Program	12/3/96

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-I: EPA/DOE CORRESPONDENCE AND ACTIVITIES AFTER
PUBLICATION OF THE ANPR DATED NOVEMBER 15, 1996**

NO.	Date Sent to Docket	COMMENTS/ADDRESSEE Title and/or Subject	Date of Document
II-I-09	2/27/97	Ltr/EPA/R. Trovato to DOE-CAO/G. Dials requesting data record packages	2/18/97
II-I-10	3/7/97	Ltr/DOE-CAO/G. Dials to EPA/R. Trovato -fifth response package to EPA's letter of December 19, 1996 to DOE/A. Alm. Supplemental Information for the Compliance Certification Application(CCA) includes the following: <u>Response to EPA Comments . Enclosure 1:</u> <ul style="list-style-type: none"> a. 194.14(a)(2) Content of CCA b. 194.22(a)(2)(iii) Quality Assurance (Models and Computer Codes) c. 194.23(a)(3)(ii) Models and Computer Codes d. 194.23(a)(3)(iii) Models and Computer Codes e. 194.23(a)(3)(iv) Models and Computer Codes f. 194.24(c) and 194.24(c)(1) Waste Characterization g. 194.24(c)(4) Waste Characterization h. 194.24(g) Waste Characterization i. 194.25(b)(i) Future State Assumptions j. 194.53 Consideration of Underground Sources of Drinking Water <u>Response to EPA Comments. Enclosure 2</u> <ul style="list-style-type: none"> a. 194.14(a)(2) Content of CCA b. 194.23(a)(3)(i) Models and Computer Codes c. 194.23(a)(3)(i) Models and Computer Codes d. 194.23(a)(3)(iv) Models and Computer Codes e. 194.23(c)(2) Models and Computer Codes f. 194.34(c) Results of Performance Assessments g. 194.44 Engineered Barriers h. 194.51 Consideration of Protected Individual 	2/26/97
II-I-11	3/7/97	Ltr/EPA/R. Trovato to DOE-CAO/G. Dials, scheduling audit of Sandia's QA Program	1/7/97
II-I-12	3/7/97	Ltr/DOE-CAO/G. Dials to EPA/R. Trovato, responding to EPA letter of 2/18/97 requesting data record packages	2/27/97
II-I-13	3/18/97	Summary of EPA/DOE Meeting held on March 5, 1997	3/7/97
II-I-14	3/18/97	Summary of EPA/DOE Meeting held on March 6, 1997	3/7/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-I: EPA/DOE CORRESPONDENCE AND ACTIVITIES AFTER
PUBLICATION OF THE ANPR DATED NOVEMBER 15, 1996**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-I-20	4/10/97	Summary of EPA/DOE Meeting held on March 26, 1997	4/3/97
II-I-21	4/10/97	Summary of EPA/DOE Mtg. held on April 3, 1997	4/3/97
II-I-22	4/10/97	Summary of EPA/DOE/Commerce Committee Mtg. Held on March 14, 1997	4/7/97
II-I-23	4/17/97	Summary of EPA/DOE Meeting held on April 14, 1997	4/16/97
II-I-24	4/23/97	Ltr/G. Dials/DOE-CAO to EPA/R. Trovato, responding to March 19, 1997 letter to DOE/A/ Alm regarding CCA issues/comments, as follows: Comment No. 2 Data Quality Characteristics Comment No. 3 E2 After E2 Scenarios Comment No. 9 More Information on Permeability and Porosity Versus Pressure Curves Comment No. 12 Does DOE want to Include Other than BIR Data? Comment No. 13 Adsorption of Actinides for Cuttings/Caving Comment No. 14 Details on HYDRAQL code Comment No. 15 Uncertainties on Upper and Lower Limits Comment No. 16 Detail on Methods of NDA Comment No. 17 Support an EPA Audit of WWIS Comment No. 19 Contaminant Transport from Brine Flow from a Single Hole	4/15/97
II-I-25	4/23/97	Ltr/EPA/R. Trovato to DOE/CAO/G. Dials, follow-up to EPA letter of March 19, 1997 to Doe/Alm regarding performance assessment input parameters with two enclosures as follows: Enclosure 1 - Parameters no longer in question. Enclosure 2 - Parameters not representative of the data.	4/17/97
II-I-26	5/1/97	Ltr/DOE/G. Dials to EPA/R. Trovato re: DOE's Plan to Respond to Issues Raised in EPA's ltr of March 19, 1997 to DOE/Alm	4/11/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-I: EPA/DOE CORRESPONDENCE AND ACTIVITIES AFTER
PUBLICATION OF THE ANPR DATED NOVEMBER 15, 1996**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-I-31	5/20/97	Ltr/DOE-CAO/G. Dials to EPA/R. Trovato third response to EPA's letter of March 19, 1997 to DOE/A. Alm regarding CCA issues/comments. Supplemental information includes responses to Enclosures 1 of the March 19, 1997 letter as follows: <div style="margin-left: 40px;"> <p>Comment No. 1 - Origin of Hydrochemicals Facies and Modeled Paleoflow Directions</p> <p>Comment No. 4 - SECOTP2D - Test with a Heterogeneous T-Field</p> <p>Comment No. 5 - SECOTP2D - Mass Balance</p> <p>Comment No. 6 - Quantity Impacts of Code Errors</p> <p>Comment No. 7 - SECOTP3D Code Test Results</p> <p>Comment No. 8 - Benchmark NUTS with SWIFT</p> <p>Comment No. 11 - Traceability of Development of Legacy Parameters</p> <p>Comment No 20/22 - Solution Mining</p> </div>	5/14/97
II-I-32	5/21/97	Ltr/DOE-CAO/G. Dials to EPA/R. Trovato transmitting the report of the NEA/IAEA, International Review Group entitled "International Peer Review of the 1996 Performance Assessment of the US Waste Isolation Pilot Plant (WIPP)" dated April, 1997	5/2/97
II-I-33	6/11/97	Performance Assessment Parameter Values Identified in EPA letters to DOE dated April 17 and 25 1997	6/6/97
II-I-34	6/18/97	Ltr/DOE-CAO/G. Dials to EPA/L. Weinstock transmitting the final report on "Expert Elicitation on WIPP Waste Particle Size Distribution(s) During the 10,000-Year Regulatory Post-Closure Period" (Report filed A-93-02, II-G-24	6/4/97
II-I-35	6/18/97	Ltr/DOE-CAO/J. Mewhinney to EPA/F. Marcinowski transmitting draft reports on "Results of the MgO Backfill Efficacy Investigation" (Filed A-93-02, Item II-A-39) and "Description and Evaluation of a Mechanistically Based Conceptual Model for Spall " (Filed A-93-02, Item II-G-23)	6/2/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-I: EPA/DOE CORRESPONDENCE AND ACTIVITIES AFTER
PUBLICATION OF THE ANPR DATED NOVEMBER 15, 1996**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-I-43	8/15/97	Summary of DOE/EPA telephone conversations of August 11, 1997	8/11/97
II-I-44	8/21/97	Summary of DOE/EPA telephone conversation of August 15, 1997	8/18/97
II-I-45	8/27/97	Summary of DOE/EPA telephone conversation of August 11, 1997	8/19/97
II-I-46	8/27/97	Summary of DOE/EPA telephone conversation of August 19, 1997	8/19/97
II-I-47	8/27/97	Summary of DOE/EPA meetings of August 18, 1997	8/20/97
II-I-48	8/27/97	Summary of DOE/EPA OGC facsimile of August 20, 1997	8/20/97
II-I-49	8/27/97	Ltr/DOE/CAO/G. Dials, to EPA/L. Weinstock transmitting final results of the EPA mandated Performance Assessment Verification Test (PAVT). (This document is filed at A-93-02, Item II-G-28)	8/11/97
II-I-50	8/27/97	Summary of DOE/EPA telephone conversations of Aug. 26-and 27/97	8/27/97
II-I-51	9/4/97	Ltr/DOE transmittal letter with enclosure 1 for the approved Performance Demonstration Program Plan for Nondestructive Assay for the TRU Waste Characterization Program, CAO-94-1045, Rev. 1 dated May, 1997 (Enclosure 2). (This document is filed docket A-93-02, Item II-G-31)	6/3/97
II-I-52	9/4/97	Ltr/DOE/D. Brown - QA Manager to EPA/M. Kruger transmitting two papers as follows: a. Data Quality Characteristics in the WIPP Compliance Certification Application (3 pages) b. The WIPP Project Approach to the Assessment of Quality Characteristics (7 pages)	8/15/97
II-I-53	9/4/97	Ltr/DOE/J. Mewhinney to EPA/F. Marcinowski transmitting CCA Records from the Carlsbad Area Office (Information docketed at A-93-02, II-G-32) .	8/25/98
II-I-54	9/4/97	Summary of DOE/EPA telephone conversation of August 26, 1997 - C. Byrum - EPA and G. Froelich-DOE	8/26/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

**CATEGORY II-I: EPA/DOE CORRESPONDENCE AND ACTIVITIES AFTER
PUBLICATION OF THE ANPR DATED NOVEMBER 15, 1996**

NO.	Date Sent to Docket	COMMENTER/ADDRESSEE Title and/or Subject	Date of Document
II-I-64	9/16/97	Summary of DOE/EPA staff attorneys meeting of August 29, 1997 regarding requirements of 40 CFR 194.24	9/8/97
II-I-65	9/16/97	Ltr/DOE/G. Dials to EPA/L. Weinstock, transmitting Summary of the EPA-Mandated Performance Assessment Verification Test Results for the Individual and Groundwater Protection Requirements, WPO#47258 dated 9/12/97. (This document is filed A-93-02, item II-G-39)	9/15/97
II-I-66	9/16/97	Summary of the EPA/DOE teleconference calls concerning Scale-Up Procedures for CCA between EPA/T. Wolbarst and M. Chu/DOE-SNL on September 3 and 4, 1997	9/16/97
II-I-67	9/16/97	Summary of the EPA/DOE telephone calls concerning Waste Unit Factor/Organ Doses between EPA/T. Wolbarst and M. Chu/DOE-SNL on September 11 and 15, 1997	9/16/97
II-I-68	9/29/97	Ltr/DOE-CAO/G. Dials to EPA/L. Weinstock regarding Doses Predicted from Results of the EPA mandated Performance Assessment Verification Test with attachments: Atch 1 - WPO#47309 - Summary of the EPA-Mandated Performance Assessment Verification Test Results for Individual Protection Requirements: Estimated Doses to Internal Organs and Total Body from Groundwater Ingestion and to the Total Body from Beef Consumption, Vegetable Consumption and Inhalation of Soil, dated 9/22/97 (This document filed A-93-02, II-G-40) Atch 1 - WPO#47308 - Analysis Report of an Evaluation of the Dose Contributions from Beta, Electron and Photon Emissions to Critical Organs Related to Drinking Water Consumed for the Undisturbed Performance supporting the Compliance Certification Application, dated 9/22/97 (This document is filed A-93-02, II-G-41)	9/22/97
II-I-69	9/29/97	Memo to the file, EPA/OGC, K. Matthews, transmitting document provided by DOE/OGC titled "Information in the Compliance Certification Application that Demonstrates compliance with Section 194.24"	9/18/97

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY III-A: NOTICE OF PROPOSED RULEMAKING

NO.	Date Sent to Docket	COMMENTS/ADDRESSEE Title and/or Subject	Date of Document
III-A-1	10/14/97	Proposed Compliance Certification Decision -	

**DOCKET NO: A-93-02 (CERTIFICATION RULEMAKING)
40 CFR 191 COMPLIANCE DETERMINATION FOR THE WASTE ISOLATION
PILOT PLANT (WIPP)**

CATEGORY III-B: PROPOSED SUPPORT DOCUMENTS

NO.	Date Sent to Docket	COMMENTS/ADDRESSEE Title and/or Subject	Date of Document
III-B-15	10/14/97	Technical Support Document for Section 194.24: WIPP Facility and Waste Characterization	
III-B-16	10/14/97	Technical Support Document for Section 194.24: EPA's Evaluation of DOE's WIPP Waste Information System (WWIS)	
III-B-17	10/14/97	Technical Support Document for Section 194.24: EPA's Evaluation of DOE's Actinide Source Term	
III-B-18	10/14/97	Technical Support Document for Section 194.24: Waste Characterization Status of INEL, LANL, RFETS	
III-B-19	10/14/97	Technical Support Document for Section 194.24: Analysis of TWBIR, Revision 3	
III-B-20	10/14/97	Technical Support Document for Section 194.25: Future States	
III-B-21	10/14/97	Technical Support Document for Section 194.32: Scope of Performance Assessments	
III-B-22	10/14/97	Technical Support Document for Section 194.32: Fluid Injection Analysis	
III-B-23	10/14/97	Technical Support Document for Section 194.34: Use of CCDF Formalism in the WIPP PA, An EPA Background Document	
III-B-24	10/14/97	Technical Support Document for Section 194.43: Passive Institutional Controls - Implementation Cost Estimate	
III-B-25	10/14/97	Technical Support Document for Sections 194.51, 194.52, and 194.55: Dose Verification Evaluation	
III-B-26	10/14/97	Technical Support Document for Section 194.55: Compliance Assessment Statistics	
III-B-27	10/14/97	Technical Support Document for the LWA: Lease Evaluation	